27736

National Library of Canada | Bibliothèque nationale du Canada

CANADIAN THESES ON MICROFICHE

THÈSES CANADIENNES SUR MICROFICHE

NAME OF AUTHOR/*NOM DE L'AUTEUR* LYNNE SIGLER

TITLE OF THESIS/*TITRE DE LA THÈSE* TAXONOMY OF MALBRANCHEA AND SOME OTHER HYPHOMYCETES WITH ARTHROCONIDIA

UNIVERSITY/*UNIVERSITÉ* UNIV. OF ALBERTA EDMONTON

DEGREE FOR WHICH THESIS WAS PRESENTED/ *GRADE POUR LEQUEL CETTE THÈSE FUT PRÉSENTÉE* MSc

YEAR THIS DEGREE CONFERRED/*ANNÉE D'OBTENTION DE CE GRADE* 1976

NAME OF SUPERVISOR/*NOM DU DIRECTEUR DE THÈSE* DR. J. W. CARMICHAEL

Permission is hereby granted to the NATIONAL LIBRARY OF CANADA to microfilm this thesis and to lend or sell copies of the film.

The author reserves other publication rights, and neither the thesis nor extensive extracts from it may be printed or otherwise reproduced without the author's written permission.

L'autorisation est, par la présente, accordée à la BIBLIOTHÈQUE NATIONALE DU CANADA de microfilmer cette thèse et de prêter ou de vendre des exemplaires du film.

L'auteur se réserve les autres droits de publication; ni la thèse ni de longs extraits de celle-ci ne doivent être imprimés ou autrement reproduits sans l'autorisation écrite de l'auteur.

DATED/*DATÉ* Dec 16/75 SIGNED/*SIGNÉ* Lynne Sigler

PERMANENT ADDRESS/*RÉSIDENCE FIXE*
DEPT. MEDICAL BACTERIOLOGY.
UNIV. OF ALBERTA
- 131 MEDICAL SCIENCES BLDG.

NL-91 (3-74)

INFORMATION TO USERS

THIS DISSERTATION HAS BEEN
MICROFILMED EXACTLY AS RECEIVED

This copy was produced from a microfiche copy of the original document. The quality of the copy is heavily dependent upon the quality of the original thesis submitted for microfilming. Every effort has been made to ensure the highest quality of reproduction possible.

PLEASE NOTE: Some pages may have indistinct print. Filmed as received.

Canadian Theses Division
Cataloguing Branch
National Library of Canada
Ottawa, Canada K1A 0N4

AVIS AUX USAGERS

LA THESE A ETE MICROFILMEE
TELLE QUE NOUS L'AVONS RECUE

Cette copie a été faite à partir d'une microfiche du document original. La qualité de la copie dépend grandement de la qualité de la thèse soumise pour le microfimage. Nous avons tout fait pour assurer une qualité supérieure de reproduction.

NOTA BENE: La qualité d'impression de certaines pages peut laisser à désirer. Microfilmée telle que nous l'avons reçue.

Division des thèses canadiennes
Direction du catalogage
Bibliothèque nationale du Canada
Ottawa, Canada K1A 0N4

THE UNIVERSITY OF ALBERTA

TAXONOMY OF *MALBRANCHEA* AND SOME OTHER HYPHOMYCETES WITH ARTHROCONIDIA

by

©
LYNNE SIGLER

A THESIS
SUBMITTED TO THE FACULTY OF GRADUATE STUDIES AND RESEARCH
IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE DEGREE
OF MASTER OF SCIENCE

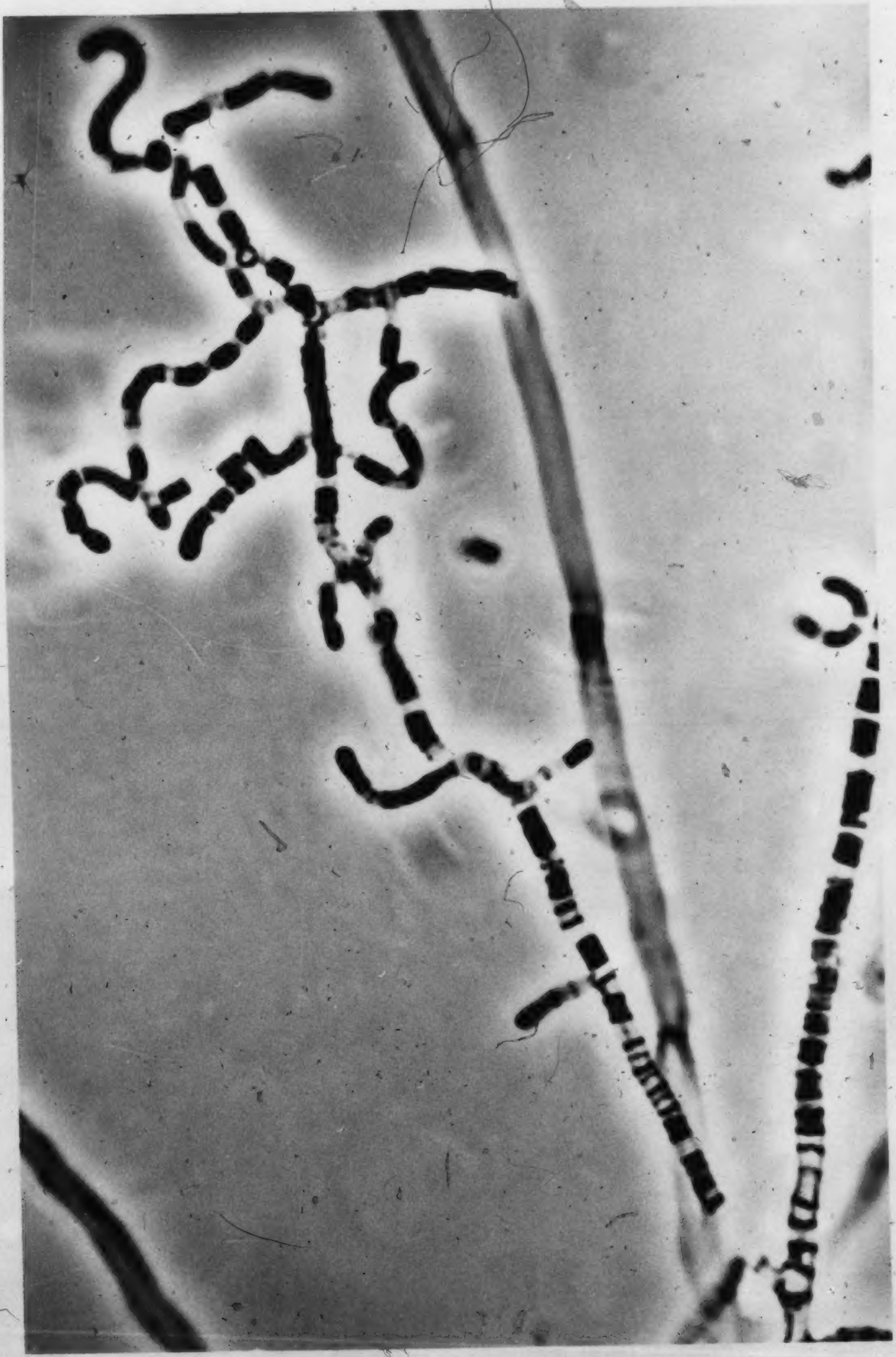
DEPARTMENT OF MEDICAL BACTERIOLOGY

EDMONTON, ALBERTA
SPRING, 1976

FRONTISPIECE

Arcuate fertile hyphae of *Malbranchea aurantiaca*

(UAMH 2844) x 1600.



THE UNIVERSITY OF ALBERTA

FACULTY OF GRADUATE STUDIES AND RESEARCH

The undersigned certify that they have read, and recommend to the Faculty of Graduate Studies and Research, for acceptance, a thesis entitled TAXONOMY OF MALBRANCHEA AND SOME OTHER HYPHOMYCETES WITH ARTHROCONIDIA submitted by Lynne Sigler in partial fulfilment of the requirements for the degree of Master of Science.

J. W. Carmichael

Supervisor

Fred D Cook

Lorene L. Kennedy

F.H. Jule

Date 8. Dec. 1975

ABSTRACT

The genus *Malbranchea* Saccardo is monographed and illustrated. The type species, *M. pulchella* is redefined and a new combination, *M. sulfurea* (Miehe) proposed for *M. pulchella* var *sulfurea*. Eleven new species are described and illustrated: *M. albolutea*, *M. arcuata*, *M. aurantiaca*, *M. chrysosporoidea*, *M. circinata*, *M. dendritica*, *M. flava*, *M. flavoroseus*, *M. flocciformis*, *M. fulva* and *M. gypsea*. A new heterothallic genus of the Gymnoascaceae is proposed for a single species, *Uncinocarpus reesii*, having a *Malbranchea* conidial state. The perfect states of some species of *Malbranchea* belong to the genera *Auxarthron* Orr, Kuehn and Plunkett and *Myxotrichum* Kunze of the Gymnoascaceae.

The relationship of *Malbranchea* to other genera is discussed and a tabular key to the genera provided. Two new genera are described. Included in the genus *Ovadendron* are the type species, *O. asperulatum*, as well as *Chrysosporium pannorum* (Link) Hughes and *Oospora sulfureo-ochracea* van Beyma. Two species are assigned to *Arcuadendron*, *A. ovatum*, the type species, and *A. triangularis*. The genus *Arthrographis* Cochet including the single species *A. langeroni* is reexamined and validated with a Latin description. *Oospora cuboidea* Sacc. et Ellis (= *Geotrichum microsporum* Smith) is transferred to this genus. Two species of *Myxotrichum* have *Oidiodendron* conidial states. The species, *M. setosum* (Eidam) Orr and Plunkett is rediscovered, and a new combination *M. striatosporus* (Barron and Booth) is proposed. The genus *Scytalidium* is expanded to include *Geotrichum flavo-brunneun* Miller, Giddens et Foster and the *Scytalidium* state of *Hendersonula toruloidea* Nattrass (= *Exosporina fawcetti* Wilson), and a key to the species is given. The status and delimitation of a number of other genera is discussed: *Bahusakala*, *Briosia*, *Chrysosporium*, *Coccidioides*, *Coremiella*, *Geotrichum*, *Oidium*, *Oospora*, *Ptychogaster*, *Sporendonema*. The arthroconidial states of some Basidiomycotina are described.

ACKNOWLEDGMENTS

Grateful appreciation is expressed to Dr. J.W. Carmichael whose expertise and knowledge of the taxonomy of Hyphomycetes has stimulated my own interest. His guidance and encouragement during the preparation of this thesis have been invaluable. Particularly helpful were his critical reviews of the manuscript and skilful clarification of some passages of the text.

My thanks are also extended to Dr. F.L. Jackson for providing the opportunity to undertake this project.

To other members of the Department of Medical Bacteriology, I express my gratitude for their willing assistance. In particular, Mrs. Suzanne Merlo skilfully translated some German text, and Dr. R.L.S. Whitehouse and Richard Sherburne offered helpful advice on some aspects of photography. Mrs. Debbie Berg expertly prepared Table I.

Thanks are also extended to other mycologists: Dr. A.S. Sekhon of the Provincial Laboratory of Public Health, who generously allowed me the use of his de Fonbrune micromanipulator, and Dr. G.F. Orr, Deseret Test Center, Dugway, Utah, who willingly provided many of the cultures used in this study. In addition, Dr. Orr was most helpful in locating some reference material.

Special appreciation is expressed to my husband, Doug, for his patience and encouragement during the past year.

TABLE OF CONTENTS

PAGE

ABSTRACT vi

ACKNOWLEDGEMENTS viii

TABLE OF CONTENTS ix

LIST OF TABLES xii

LIST OF PHOTOGRAPHIC FIGURES xiii

INTRODUCTION 1

MATERIALS AND METHODS 8

Specimens and cultures 8

Abbreviations 9

Disposition of type strains 10

Media 10

Standard culture conditions 11

Photography 14

Techniques for sexual crosses 15

Single ascospore isolation 16

Publication 16

PART I THE GENERA 18

Key to the genera 18

Arcuadendron 18

Arthrographis 26

Bahusakala 36

Arthroconidial states of Basidiomycotina 41

Briosia 49

Chrysosporium 52

Coccidioides 53

Coremiella 54
Geotrichum 56
Malbranchea 62
Oidiodendron 62
Oidium 78
Oospora 79
Ovadendron 80
Ptychogaster 90
Scytalidium 92
Sporendonema 109
PART II *MALBRANCHEA* 122
Key to the species 124
Perfect states 127
Ecology and distribution 129
Malbranchea species with arcuate fertile hyphae 131
  Malbranchea albolutea 131
  Malbranchea arcuata 140
  Malbranchea aurantiaca 142
  Malbranchea chrysosporoidea 151
  Malbranchea circinata 157
  Malbranchea flavoroseus 163
  Malbranchea pulchella 167
  Malbranchea state of *Auxarthron conjugatum* 175
  Malbranchea sulfurea 178
Malbranchea species with straight fertile hyphae 189
  Malbranchea dendritica 189
  Malbranchea flava 193
  Malbranchea flocciformis 203

Malbranchea fulva 207

Malbranchea gypsea 209

Malbranchea state of *Coccidioides immitis* 214

Malbranchea state of *Uncinocarpus reesii* 216

REFERENCES 237

APPENDIX 253

INDEX 256

LIST OF TABLES

TABLE		PAGE
I	Key to the genera	19
II	Key to the species of Scytalidium	94
III	Incompatibility among crosses of Malbranchea aurantiaca	150
IV	Diameter of agar plate colonies of Malbranchea sulfurea after growth at different temperatures	186
V	Comparison of ascocarp production in Uncinocarpus reesii by three methods of inoculation	231
VI	Summary of the fertile crosses of Uncinocarpus reesii	232

LIST OF PHOTOGRAPHIC FIGURES

FIGURE		PAGE
	Frontispiece	iv
1	*Arcuadendron*	24
2	*Arthrographis*	30
3	*Arthrographis* and *Bahusakala*	40
4	Arthroconidial states of Basidiomycotina	47
5	*Coremiella* and *Oidiodendron*	68
6	*Myxotrichum* and *Ovadendron*	76
7	*Ovadendron*, *Ptychogaster* and *Scytalidium*	88
8	*Scytalidium*	104
9	*Sporendonema*	116
10	*Malbranchea albolutea* and *M. arcuata*	134
11	*M. aurantiaca*	146
12	*M. chrysosporoidea* and *M. circinata*	155
13	*M. circinata* and *M. flavoroseus*	161
14	*M. flavoroseus*, *M. pulchella* and *M.* state of *Auxarthron conjugatum*	172
15	*A. conjugatum*, *M. sulfurea* and *M. dendritica*	180
16	*M. dendritica*, *Oncocladium flavum* and *M. flava*	201
17	*M. flocciformis* and *M. fulva*	206
18	*M. gypsea* and *M.* state of *Coccidioides immitis*	212
19	*Uncinocarpus reesii*	222
20	*Uncinocarpus reesii*	225
21	Colonial morphology	255

INTRODUCTION

In 1882, Saccardo described the genus *Malbranchea* based on a fungus found growing on damp cardboard in France. In their brief description of the type species, *Malbranchea pulchella*, Saccardo and Penzig noted the arcuate nature of the fertile hyphae, "ramulis fertilibus in semicirculum curvis". However, they misinterpreted the arthric nature of the conidia and described them as "ex apice ramulorum continuo exsilientibus". They provided no illustrations. Although *M. pulchella* was described on two other occasions (Saccardo, 1908; Saccardo and Trotter, 1913), again without illustrations, it has been largely ignored by other mycologists.

A comprehensive and well illustrated account of a thermophilic *Malbranchea* by Cooney and Emerson (1964) again focused attention on this interesting genus. Cooney and Emerson precisely described the conidium development, "roughly every other one of these cells rounds up somewhat and develops an inner wall that approaches 0.6u in thickness but remains tightly united with the original, outer, hyphal wall". "A mature sporiferous coil, therefore, is composed of alternating thick-walled spores and thin-walled isthmuses. Our own observations show clearly that it is the final breaking of these thin-walled, sterile, connecting isthmuses that results in the separation and release of the spores."

In its formation of arthroconidia by conversion of existing hyphal elements, Malbranchea is related to a number of other genera of Hyphomycetes. The problem in distinguishing among these genera is one which afflicts the classification of Hyphomycetes in general. That is, the criteria for delimiting the genera are not clearly established. The class Hyphomycetes is part of the Deuteromycotina (Ainsworth, 1973), a group composed of the imperfect or conidial states of fungi, many of which are known to have perfect states in the Ascomycotina or Basidiomycotina. Genera of the Hyphomycetes are form genera, based on a morphological or anatomical stage in the life cycle of the fungus. Unfortunately the conidial form genera do not correlate exactly with the classification of the perfect states. Morphologically similar conidial states may have unrelated perfect states, and vice versa. Current classification of Hyphomycetes is ontogenetic, grouping together fungi having the same mode of conidium development. In such a scheme, emphasis is placed upon the nature of the conidiogenous cell from which the conidium develops.

A system of cross reference names is used when the connection between the conidial state and the perfect state is known (see Carmichael, 1962; Hennebert, 1971; Kendrick and Carmichael, 1973; Weresub, Malloch and Pirozynski, 1974; Nag Raj and Kendrick, in press). When the perfect state is known, the Linnaean binomial is applied to that state alone.

The imperfect or conidial state is cross referenced by referring to the (form-genus name) state of (Linnaean binomial).

The criteria for delimitation of the arthrosporic genera have not been precisely defined. Indeed, some genera are in need of major revision. For instance, the genus Geotrichum contains a large number of diverse fungi. Geotrichum has been revised to include only species having hyaline, slimy fission arthroconidia, consistent with the type species, G. candidum. Dematiaceous species are referred to Scytalidium, others elsewhere.

The presence of a supporting hypha or conidiophore distinguishes two genera, Oidiodendron and Arthrographis, and these genera differ from each other in their conidium development.

Malbranchea, in its formation of alternate arthroconidia, is closely related to Sporendonema and Coremiella. These genera are distinguished primarily on the basis of arthroconidium diameter and color. As defined here, Malbranchea species comprise a rather homogenous group having conidium diameters of mostly less than 4um.

Two new genera are proposed. Arcuadendron forms conidia in serial progression. The conidia may be either blastic or thallic. In the genus Ovadendron, conidia are formed in basipetal succession. The intercalary arthroconidia are broader in diameter than the fertile hypha.

Taxonomic problems are encountered when species appear to intergrade between genera. These species are retained in the genus with which there is greatest overall similarity. Form genera are not biological entities but demes (Heslop-Harrison, 1962) defined by the taxonomist to separate fungi into groups for the purpose of indentification. If form genera are polythetic groups having in common a number of shared but not mutually exclusive characters, then intergrading species should be assigned to the form genus with which they have the greatest number of shared characters. For example, the *Oidiodendron* state of *Myxotrichum setosum* (q.v.) lacks the pigmented conidiophores of *Oidiodendron* but forms arthroconidia separated by the narrow connectives typical of *Oidiodendron*. This species is retained in *Oidiodendron* based on a number of other related characters. If a form genus were based on a single unique set of characters *i.e.* a monothetic group, then this species would be excluded since it differs in a definitive character. A new genus probably would be required to accommodate this species. Unfortunately, fungi do not conform to a rigid set of rules and exceptions to defined criteria are frequent. For this reason, form genera should be polythetic groups.

The same principle applies to the concept of the species. In some species of Malbranchea, single strains differing in one or more characters from the group are retained within the species. For instance, four isolates of Malbranchea aurantiaca differ in some aspects of their colonial morphology but are indistinguishable in their microscopic appearance from others in the group. Until further isolates are examined there appears to be little justification for creating additional species for these strains.

Included within the genus Malbranchea are cellulolytic and keratinolytic species which are phylogenetically probably not closely related. Indeed, some cellulolytic species have their perfect states within the genus Myxotrichum of the Gymnoascaceae whereas some keratinolytic species have their perfect states in the genus Auxarthron.

Terminology

The terms used in this report are primarily those recommended by the proceedings of the Kananaskis Conference on Fungi Imperfecti (Kendrick, 1971). However, aleurioconidium is retained here, in Vuillemin's (1911) original sense, for a conidium borne laterally or terminally on the undifferentiated hypha or on short pedicels and released by lysis of the supporting cell. Although aleurioconidium was rejected as a confused term, no other was proposed to replace it. The term refers to the method of conidium dehiscence. (see Carmichael in Kendrick, 1971, p. 245).

Aleurioconidia are closely related to alternate arthroconidia and often intergrade. The term alternate arthroconidia is preferred to endoarthroconidia for arthroconidia separated by one or more relatively empty segments, and released by lysis of the outer wall of the intervening segment. Another suitable term is arthroaleurie defined by Orr (1963b).

Fission arthroconidia are formed by fission at a double septum of an existing hypha.

The term conidiophore is retained for a differentiated hyphal structure which supports the conidia or conidiogenous cells away from the vegetative mycelium (see Carmichael, in Kendrick, 1971, p. 47). The definition accepted by the Conference (see Kendrick, 1971, p. 227) was "a conidiophore is a system of conidiogenous cells, or a single conidiogenous cell, with or without differentiated supporting structures." A conidiophore without a differentiated supporting structure is called micronematous by Ellis (1971). A micronematous conidiophore cannot be distinguished from the vegetative hypha before the process of conidium formation begins. According to the definition used in this report, fungi developing conidia on undifferentiated hyphae lack conidiophores.

Following Hughes (1959), 1801 is taken as the starting point date for nomenclature of Hyphomycetes.

MATERIALS AND METHODS

A. Specimens and cultures

At the beginning of this study, the University of Alberta Mold Herbarium and Culture Collection contained approximately 100 strains of Malbranchea that were collected over a period of 10-12 years.

Many of them were isolated by Dr. G. F. Orr (Deseret Test Center, Dugway, Utah) during his continuing studies on Gymnoascaceae. During the study, he sent a further forty cultures.

Dr. Z. Hubalek, Institute for Parasitology, Prague, sent some of the isolates made during his extensive studies of birds (Hubalek, Balat, Touskova and Vik, 1973; Hubalek and Balat, 1974; Hubalek, 1974a,1974b). Some further isolates no longer available from Dr. Hubalek were received from Dr. Orr.

Mrs. C. A. Johansen of the Western Forest Products Laboratory Culture Collection of Wood Inhabiting Fungi kindly sent several cultures of Ptychogaster.

Dr. K. Tubaki of the Institute for Fermentation, Osaka, willingly exchanged a number of cultures.

Dr. C. T. Rogerson of the New York Botanical Garden Cryptogamic Herbarium lent the isotype specimen of Oospora *cuboidea* Sacc. et Ellis. The Herbarium of the Commonwealth Mycological Institute, Kew, Surrey sent material and slides of *Oncocladium flavum* Wallr.

Further reference cultures were obtained from the Centraalbureau voor Schimmelcultures; the Commonwealth Mycological Institute; and the Department of Agriculture, Ottawa.

B. Abbreviations

ATCC	-American Type Culture Collection, Rockville, Maryland, U.S.A.
CBS	-Centraalbureau voor Schimmelcultures, Baarn, Netherlands
CDC	-Center for Disease Control, Atlanta, Georgia, U.S.A.
CMI	-Commonwealth Mycological Institute, Kew, Surrey, England
DAOM	-Department of Agriculture, Ottawa, Ontario, Canada
DSA	-Dextrose-salts agar
IFO	-Institute for Fermentation, Osaka, Japan
NRRL	-Northern Utilization Research Development Division, Peoria, Illinois, U.S.A.
NYBG	-New York Botanical Garden Cryptogamic Herbarium, N.Y., U.S.A.
PYE	-Phytone yeast extract agar
RSABG	-Rancho Santa Ana Botanic Garden, Claremont,

California, U.S.A.

UAMH -University of Alberta Mold Herbarium and Culture Collection, Edmonton, Alberta, Canada

WFPL -Western Forest Products Laboratory Culture Collection of Wood Inhabiting Fungi, Vancouver, British Columbia, Canada

C. Disposition of type strains

Dried colonies of the type strain of each new species are maintained in the UAMH as holotype. Subcultures of the type strain are deposited in the CMI, CBS and ATCC.

D. Media

Media used in the study consisted of:

1. Phytone yeast extract agar, Baltimore Biological Laboratories (BBL) - dextrose 4%; phytone 1%; yeast extract 0.5%; agar 2%; and chloramphenicol (0.05 ug/l) and streptomycin (0.03 ug/l) (Carmichael, 1962).
2. Pablum mixed cereal agar - Pablum precooked cereal (Mead Johnson Nutritionals, Evansville, Illinois) 10%; agar 1.5%.
3. Dextrose-salts agar - 0.01% of each of dextrose, sodium chloride, ammonium sulfate and dibasic potassium phosphate in 2% agar solution, and biotin (0.1 ug/l). (Carmichael, 1962).

4. Oatmeal-salts agar - rolled oats 1%; magnesium sulfate 0.1%; potassium dihydrogen phosphate 0.15%; sodium nitrate 0.1%; agar 1.8%, pH 5.6 (Weitzman and Silva-Hutner, 1967; Padhye, Sekhon and Carmichael, 1973)

E. Standard culture conditions

Detailed descriptions of each strain were charted by recording the appearance under standard conditions.

1. Cellophane plates

A single sterile (62 x 62 mm) cellophane membrane designated 300 PT (plain, transparent) was layered over the surface of an agar plate prepared in a 90 mm plastic disposable petri dish (Carmichael, 1962).

The cellulolytic ability of the fungus was determined by its capacity to digest this membrane either partially or completely.

2. Inoculum

Two week old colonies on cereal slants prepared from frozen or lyophilized cultures were maintained at 8 C as stock cultures.

A scarcely visible inoculum was transferred from the periphery of the stock culture to the center of the cellophane membrane.

Each strain was inoculated in triplicate to PYE, cereal and oatmeal agar plates.

3. Temperature

A single PYE and cereal plate was incubated at each temperature of 25 C, 37 C and 45 C for a maximum of 21 days. A single oatmeal agar plate was incubated at 18 C, 25 C and 30 C for 35 days.

Thermophilic fungi can grow at a temperature of 50 C or higher, while only scant growth occurs at 20-25 C (Cooney and Emerson, 1964). Psychrophilic fungi are capable of growth at a minimum temperature of 0 C or lower and a maximum temperature of 20-25 C (Deverall, 1968).

4. Light

Cultures for standard descriptions and mating tests were exposed to fluorescent room light on an irregular basis, usually 8-10 hours per day, 5 days per week. Cultures at 18 C were incubated in darkness with exposure to light only during examination.

5. Incubation

Most cultures were incubated in the inverted position. The few that adhered poorly to the cellophane membrane were returned to an upright position.

Cultures on PYE and cereal were held for 21 days before being photographed and dried, and those on oatmeal agar for 35 days. If cleistothecial initials appeared or cleistothecia were not mature, oatmeal plates were kept 2-4 weeks longer.

Colonies were dried by removing the cellophane membrane to a press (Carmichael, 1963).

6. Standard descriptions

Each colony on PYE and cereal was examined weekly to measure the diameter and record colony characters and presence of a diffusable pigment.

The diameter, measured in two directions perpendicular to each other, was an average of the two readings.

7. Microscopic preparations

Permanent microscopic slides were prepared by the slide culture technique or by direct mounts from the colony in polyvinyl alcohol mounting medium (Carmichael, 1962).

Occasional non-permanent slides were prepared in lacto-fuchsin (Carmichael, 1955) but the use of a phase contrast microscope alleviated the requirement for stained preparations.

8. Keratinolytic activity

The keratinolytic activity of a fungus *in vitro* was determined by the amount of digestion of the hair and the degree of penetration of the hyphae with or without the aid of penetrating bodies, when the fungus was grown on a nutritionally minimal medium (DSA) sprinkled with hair (Carmichael, 1962).

F. Photography

All photomacrography was done with a single lens reflex camera mounted on an adjustable stand. Colonies were illuminated with a single 3200 K tungsten lamp at an oblique angle and photographed with Kodak Panatomic X, a fine grain moderate speed film. Illustrative plates were rephotographed using Panatomic X film and four 3200 K lamps.

Color transparencies were obtained using Kodak Hi Speed Ektachrome film, a reversal film for tungsten light. Some color resolution was sacrificed in conversion of transparencies to prints.

Kodak Hi Contrast Copy film, a fine grain high resolution film was used for all photomicrography.

Illustrative plates were rephotographed with Panatomic X film so as not to further increase contrast.

G. Techniques for sexual crosses

Procedures for mating heterothallic species of the Gymnoascaceae especially of the genera *Arthroderma* and *Nannizzia* are well established (Dawson and Gentles, 1961; Padhye, 1969; Padhye and Carmichael, 1969, 1971, 1972, 1973). Early reports indicated that soil sprinkled with a keratin source such as feathers, hair, nail, hoof, *etc*. was superior to an agar medium (Dawson and Gentles, 1961; Dawson, Gentles and Brown, 1964; Stockdale, 1963). However, more recent studies (Weitzman, Kozma, and Silva-Hutner, 1969; Padhye *et*. *al*., 1973) indicate that a non-keratinous agar such as the oatmeal-salts agar (medium E) of Weitzman and Silva-Hutner (1967) stimulated excellent production of ascocarps.

The inoculum was from the periphery of a 14 day old culture grown at 25 C on cereal agar. Three different methods of inoculation to oatmeal-salts agar were attempted:

A. Premixed conidial suspensions were prepared by removing a small inoculum from each of two tester strains to 1 ml of sterile distilled water in a test tube. The suspension was mechanically agitated and pipetted onto the medium.

B. A conidial suspension of a single tester strain was prepared as in A, and a few drops from each of two strains pipetted to the agar plate, then mixed.

C. Loopsful from the conidial suspension of each of two tester strains were inoculated onto oatmeal agar in separate parallel streaks.

If the organism was known to utilize keratin some sterile hairs from an adult blonde woman were sprinkled over the agar.

Crosses were observed weekly to six weeks when cleistothecia were reported. Plates were retained up to 56 days before being discarded as negative.

H. Single ascospore isolation

A single mature fertile cleistothecium removed to a welled slide containing 2-3 drops of sterile distilled water, was shaken to remove conidia and transferred to a second well where it was crushed. The suspension of ascospores and peridial hyphae was pipetted onto a PYE plate and single ascospores isolated with the aid of a de Fonbrune micromanipulator. After 24 hours incubation at 25 C, single germinating ascospores were transferred to PYE or oatmeal plates.

I. Publication

This thesis is not intended to constitute valid publication of the new names and combinations proposed herein.

PART I THE GENERA

KEY TO THE GENERA .... Table I

Arcuadendron Sigler et Carmichael gen. nov.

Diagnosis

Vegetative hyphae hyaline or yellowish green, septate; conidiophores lacking. Conidiogenous cells are integrated, serial, indeterminate, progressive, growing from the apical conidium. Conidia are blastic, or thallic, serial, alternate, separated by short, branched or unbranched, hyphal segments and released by dissolution of the intervening cells. Conidia are broadly ellipsoidal or triangular with truncate ends, hyaline or yellowish in color, smooth or verrucose.

Type species: *Arcuadendron ovatum* Sigler et Carmichael sp. nov.

Discussion

Arcuadendron differs from *Malbranchea* in that the fertile hypha increases in length after the formation of each conidium. In *Malbranchea* the hypha ceases growth before conversion to alternate arthroconidia occurs. In both, however, conidium dehiscence occurs by dissolution of

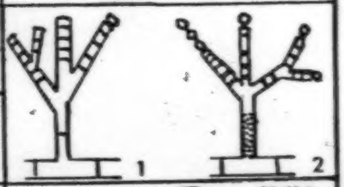
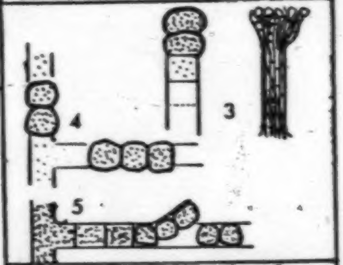
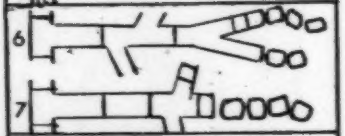
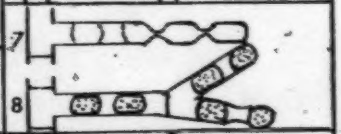
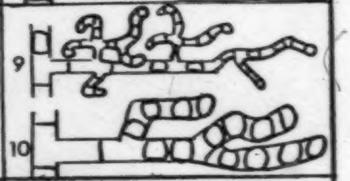
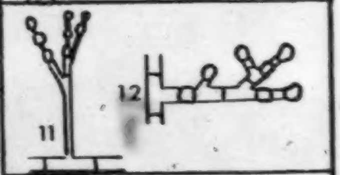
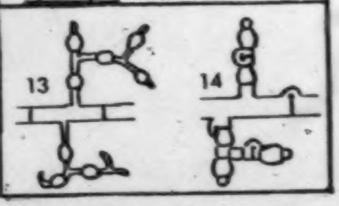
TABLE I

KEY TO THE GENERA

Genera	Conidiogenous Hypha	Conidiogenous Cells	Conidia
1 Arthrographis	Determinate	Retrogressive	Basipetal Chains
2 Oidiodendron			
3 Briosia			
4 Scytalidium			Random or Simultaneous
5 Bahusakala			
6 Geotrichum			
7 Basidiomycotina			Random or Alternate
8 Coremiella			Alternate Chains
9 Malbranchea			
10 Sporendonema			
11 Ovadendron			
12 Chrysosporium			Alternate or Single
13 Arcuadendron	Indeterminate	Serial Progressive	Acropetal Chains
14 Ptychogaster			

*On natural substrate but not necessarily in culture

TABLE I CONTINUED

Diameter of Conidium Compared to Fertile Hypha	Dehiscence	Color of Conidia	Differentiated Conidiophores	Figure
Same Width	Fission	Light Colored	Unpigmented	
			Mostly Pigmented	
Broader		Dark Colored	Coremia*	
Broader or Same Width			Absent	
Same Width		Hyaline		
	Fission or Fracture			
	Fracture or Lysis	Dark Colored	Coremia*	
		Light Colored	Absent	
Broader			Unpigmented or Absent	
			Absent	
			Sporodochia*	

the intervening segments.

Arcuadendron ovatum Sigler et Carmichael sp. nov.

Description

Colonies on PYE (Figs. 1A,1B) grow moderately rapidly (37-39 mm in 21 days) and are drab violet with white or pinkish violet center, reverse dark purple. In appearance, the colony is suede-like, flat with raised center and sharp outward radiating folds developing cracks near the center (Fig. 1A), or floccose, flat near the periphery, but rising to a central plateau, smooth (Fig. 1B). Growth at 37 C is similar, 25-36 mm in 21 days, drab violet, dark violet reverse, downy with few folds at the center or entirely cerebriform (Figs. 1C,1D).

On cereal, colonies (Figs. 1E,1F) attain the same diameter. Surface growth is violet, reverse dark violet, but the aerial growth is pale buff, floccose, slightly raised with flat central plateau and glabrous margin (Fig. 1E), or yellow, powdery and flat, sectoring near the margin (Fig. 1F). The violet surface pigment does not diffuse into the agar. Colonies at 37 C grow somewhat slower (18-32 mm at 21 days) and show less luxuriant aerial growth.

The optimum temperature range is 25 C - 30 C.

Vegetative hyphae are hyaline or greenish yellow, septate. Conidia are blastic, developing serially on undifferentiated hyphae (Fig. 1G). The fertile hypha is curved (Figs. 1H,1I), narrow, 1.0-1.5um in diameter, arising as a lateral branch from the broader vegetative hypha. Conidiogenous cells are undifferentiated from the fertile hypha, holoblastic. A marked increase in volume precedes delimitation of the conidium by a basal septum (Fig. 1J). The hypha continues to grow from the apical part of the conidium (Fig. 1J), often branching, and the conidium is delimited by an apical septum. Mature conidia (Fig. 1K), released by dissolution of the intervening hyphal segments are truncate, broadly ellipsoidal, verrucose at maturity, hyaline at first, later greenish-yellow, 3-4.5um x 4-7(9)um.

No other spore state was observed and an attempt to cross the isolates was unsuccessful.

Holotype: soil, India, UAMH 2737

Habitat and Activities

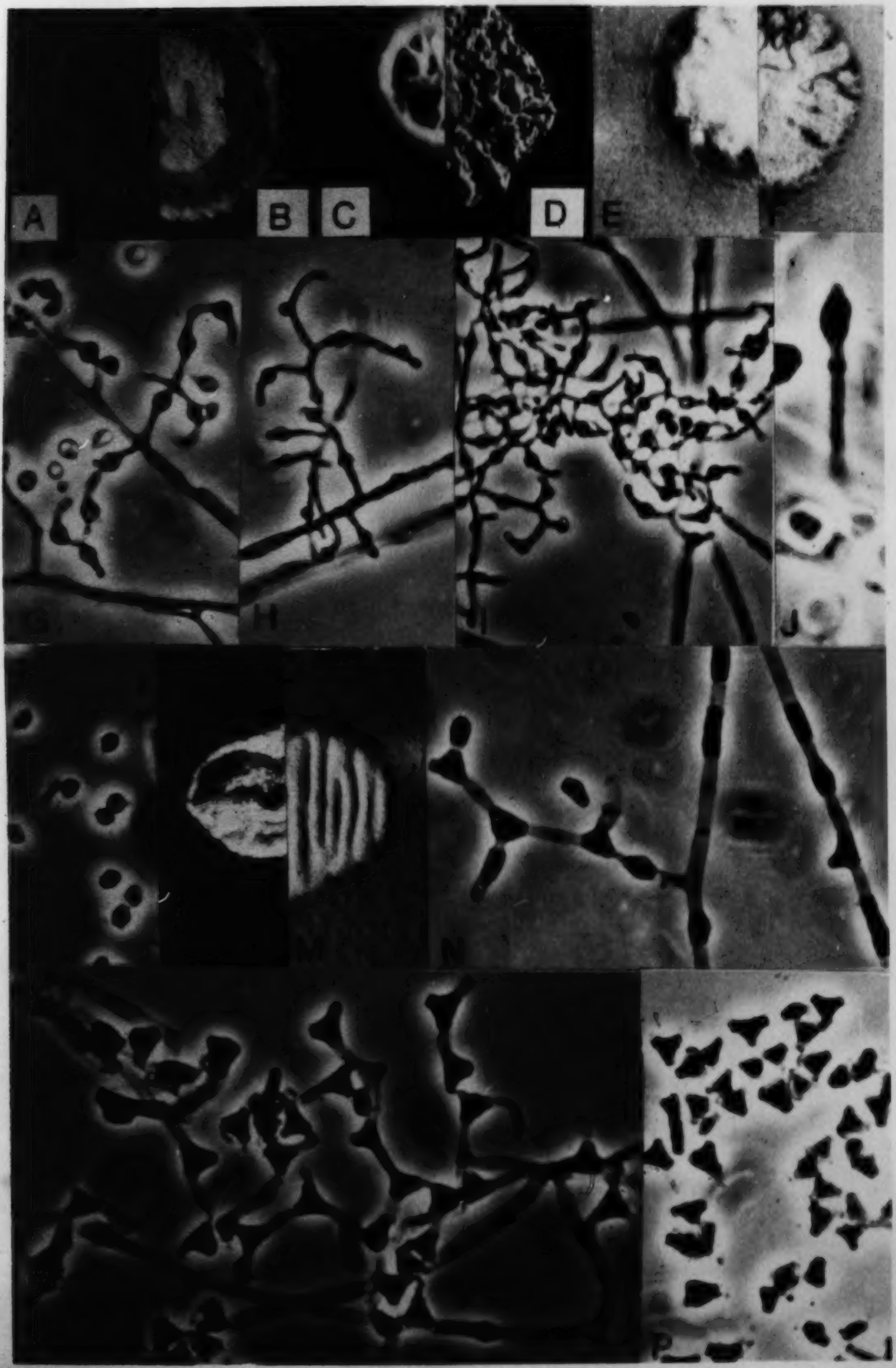
Two strains were isolated in India, one from soil, the other from an ulcer in a monkey.

A. ovatum is cellulolytic but does not attack keratin.

Material Examined

UAMH 2737, soil, India, from H.C. Gugnani, National

Figure 1. A-K. _Arcuadendron_ _ovatum_ (A,D,F,G,J-UAMH 2737; B,C,E,H,I,K-2746). L-P. _Arcuadendron_ _triangularis_ (3433). Figs. 1A-1F. Colonial morphology after 21 days. A-D on PYE, E and F on cereal. C and D at 37 C, rest at 25 C. Figs. 1G-1I. Blastic conidia developing serially on curved fertile hyphae. Fig. 1J. Blastic conidium delimited by basal septum. Fig. 1K. Mature verrucose conidia. Figs. 1L-1M. Colonial morphology after 21 days at 25C. L on PYE, M on cereal. Figs. 1N-1O. Chains of triangular conidia developing serially on undifferentiated hyphae. Fig. 1P. Mature triangular conidia. Colonies x1.0, others x 830, except J, x 2300.


A
B
C
D
E
G
H
I
J
M
N
P

Institute of Communicable Diseases, New Delhi as S252; UAMH 2746, ulcer in a monkey, India, from H.C. Gugnani as M5259.

Arcuadendron triangularis Sigler et Carmichael sp. nov.

Description

The colony (Fig. 1L) on PYE is slow growing, reaching a diameter of 20 mm in 21 days, creamy white, reverse light brown, raised and convoluted, dense, tough, powdery with tiny cracks across the surface. Pale yellow droplets of exudate appear on the surface.

On cereal (Fig. 1M) the colony is flatter, spreading to a diameter of 25 mm in 21 days with deep folds running parallel across the diameter of the colony, white, reverse buff, powdery.

There is no growth at 37 C; the optimum temperature is 25 C.

The vegetative hyphae are hyaline, septate, broad, 2.5-4um in diameter, often forming prominent racquet hyphae. Conidia are thallic, developing serially within an undifferentiated hypha, at first cylindrical in shape, then expanding in volume on one side to become triangular in shape (Fig. 1N). Meristematic growth continues until the conidium is delimited by a septum (Fig. 1,O). The curved fertile hypha grows from the apex of the triangular conidium, forming conidia at regular intervals (Fig. 1,O). Conidia (Fig. 1P), released by disintegration of the intervening hyphal segments, are hyaline, smooth, triangular, more or less equilateral in shape, measuring 6-7um along the perpendicular from the apex to the base.

Holotype: hair of Clethrionomys glareolus, Hercegovina, Yugoslavia, Hubalek (BH68), 1970, UAMH 3433 (Orr-3351)

Habitat and Activity

Only the single strain from Yugoslavia has been examined.

A. triangularis digests cellophane but fails to attack keratin.

Arthrographis Cochet 1939

Diagnosis

Vegetative hyphae septate, branched, hyaline. Conidiophores simple, hyaline, branched at the apex, appearing arborescent. Fission arthroconidia formed by disjunction and segmentation of hyaline fertile branches borne at the apex of the conidiophore, or formed by fragmentation of undifferentiated hyphae, are hyaline or yellow, smooth, cylindrical, appearing discoid in end view.

Discussion

The genus Arthrographis proposed by Cochet (1939) for a single species, A. langeroni though adequately described and illustrated was invalidly published since Cochet did not include a Latin diagnosis. Arthrographis bears considerable resemblence to both Geotrichum and Oidiodendron. It differs from Geotrichum in forming dry fission arthroconidia on conidiophores. The conidiophores of Arthrographis lack the characteristic pigmentation of Oidiodendron. Most species of Oidiodendron develop rough-walled conidia some of which are strongly pigmented. Furthermore, Arthrographis lacks the connectives between maturing arthroconidia found in Oidiodendron (Barron, 1961, 1962; Cole and Kendrick, 1969).

Type Species

Arthrographis langeroni Cochet 1939, Ann. Parasit. Hum. Comp. 17:98-101 and pl. 3

= Oidiodendron kalrai Tewari et Macpherson 1971, Mycologia 63:602-611

Description

Colonies on PYE (Fig. 2A) are slow growing (22-28 mm at 21 days), yellow at first but characteristically buff or tan with tan reverse, slightly raised, dome shaped, downy or tufted becoming velvety and tough, or powdery. The surface remains smooth or develops radial ridges or folds which may crack.

On cereal agar (Fig. 2B) colonies are flat, creamy white or buff, powdery, occasionally downy or woolly with tufts of upright hyphae, and reach a diameter of 36-44 mm in 21 days.

Growth at 37 C is slightly less rapid.

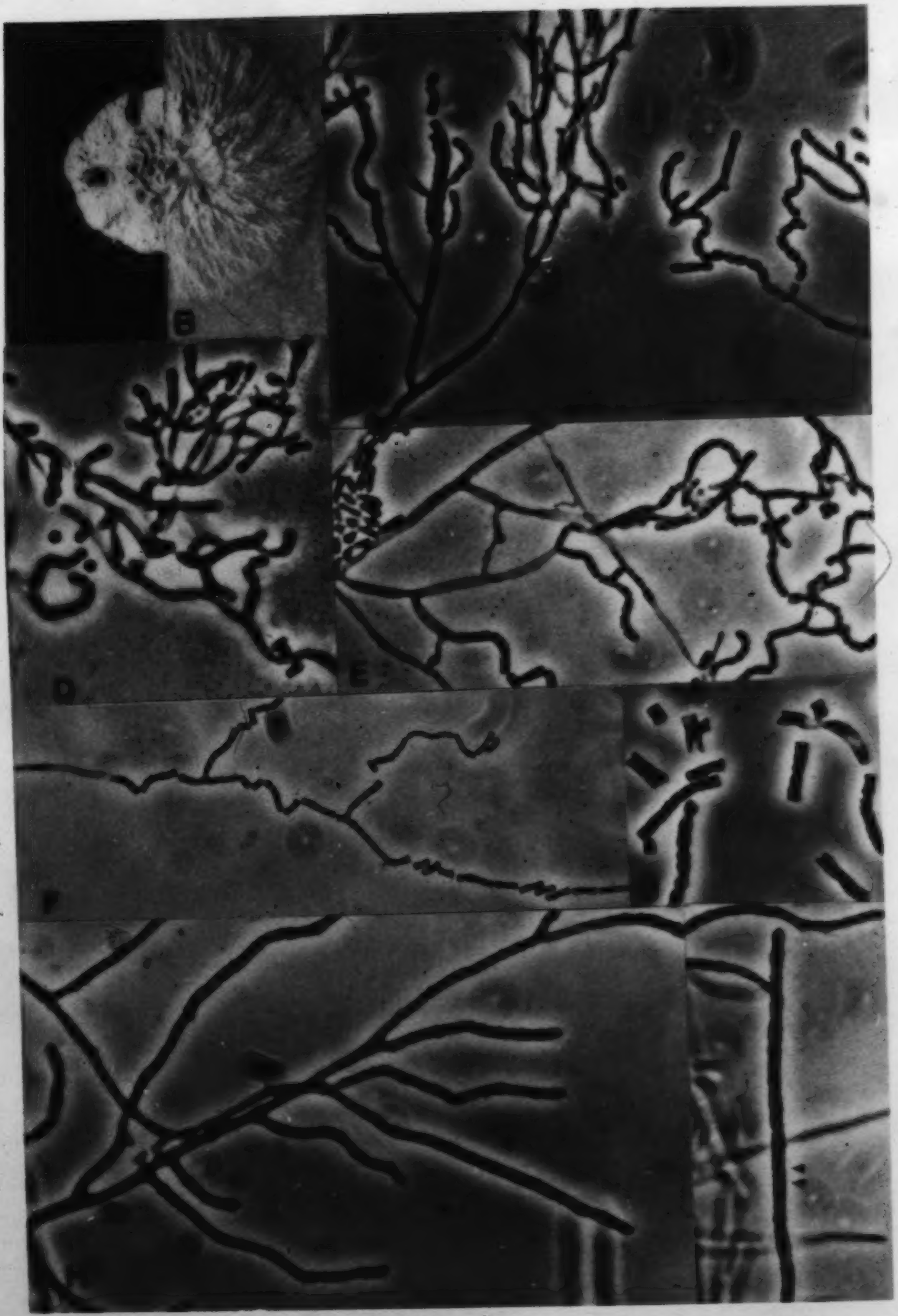
The vegetative hyphae are narrow, 1-3um in diameter. Arthroconidia, borne on short conidiophores developing multiple branches (Figs. 2C-2E), are cylindrical, hyaline, smooth, thin-walled, 1.5-2 x 2.5-4.5(5)um. During early growth, arthroconidia also develop by fragmentation of undifferentiated hyphae, but the conidia are longer and narrower (Fig. 2F). In degenerate strains, this form may predominate.

Habitat and Activities

Occurrence: *A. langeroni* has been recovered from soil, air, and human sources and appears to have a world-wide distribution.

Pathogenicity: The pathogenicity of this species has been studied by Cochet and by Tewari and Macpherson (1968b, 1971). Experimental inoculation into mice (Tewari and Macpherson, 1968b) resulted in severe neurological disorder,

Figure 2. A-F. Arthrographis langeroni (A,B-UAMH 3616; C-2617; D-3380; E-2610; F-2578). G-I. Arthrographis cuboidea (G-3760; H,I-676). Figs. 2A-2B. Colonial morphology after 21 days at 25 C. A on PYE, B on cereal. Figs. 2C-2E. Fission arthroconidia borne on branched conidiophores. Fig. 2F. Arthroconidia formed by fission of undifferentiated hyphae. Fig. 2G. Fertile hyphae and arthroconidia of isotype specimen of Oospora cuboidea. Fig. 2H. Septation of sporogenous hyphae at regular intervals. Fig. 2I. Subdivision of intervals by septa (arrows). Colonies x 1.0, others x 830.


B
D
E
F

more severe in mice inoculated intravenously than intraperitoneally. The organism was recovered from the spleen, kidney, liver, lung and brain. Tewari and Macpherson (1971) also discussed the dimorphic nature of the fungus. However, attempts to convert the type strain of _O_. _kalrai_ and Cochet's strain, a somewhat degenerate isolate, to the yeast phase by the _in vitro_ method outlined by them have been largely unsuccessful. Three morphological variants were isolated from sectors in Y-4, (ATCC 18434, UAMH 3616), the type of _O_. _kalrai_. All three formed mucoid colonies at 37 C, but only one (UAMH 3616c) formed few yeast-like budding cells after multiple transfers in brain heart infusion broth (Difco). The predominant growth throughout was hyphae and arthroconidia which often showed germination from the terminus.

Antigenicity: Tewari and Macpherson (1968a) observed significant protection in mice challenged with _Histoplasma caspulatum_ after vaccination with formalinized _O_. _kalrai_ vaccine (45% mortality) compared to 100% mortality with mice immunized by living _O_. _kalrai_. In contrast, the non-immunized controls had a mortality of 85%.

Further studies conducted by Tewari, Macpherson and Maitra (1969) demonstrated cross-reactivity of _O_. _kalrai_ with _H_. _capsulatum_. Guinea pigs sensitized by _H_. _capsulatum_ or _O_. _kalrai_ revealed cross-reactive hypersensitivity when the animals were skin tested by either histoplasmin or oidiodendrin. In serological tests, antisera of *H. capsulatum* reacted with both histoplasmin and oidiodendrin whereas antisera of *O. kalrai* reacted only with oidiodendrin.

Activity: *A. langeroni* does not attack cellophane, but digests keratin slightly often with penetration of the hair shaft by single hyphae.

Material Examined

From human sources: UAMH 3464, TYPE strain, chronic digital lesions, France, by Cochet, circa 1939, from CBS as strain Cochet 112.38; UAMH 3616, TYPE strain of *Oidiodendron kalrai*, from sputum of man with ill-defined respiratory ailment, India, Tewari (Y-4), from ATCC as 18434; UAMH 2298, also received as strain Y-4, listed as soil isolate, New Delhi, by Mohapatra, from C. Campbell, Harvard University; UAMH 2610, UAMH 2617, isolates from mixed culture also containing *Ctenomyces serratus*, received as Y-4, New Delhi, Mohapatra, from Tewari, Columbus, Ohio; UAMH 2546, gastric wash specimen, Edmonton, 1965; UAMH 3380, skin of right foot (isolated on 3 occasions), from L. Friedman, New Orleans as 192; UAMH 3715, human source, California, from Orr as O-2556;

From other sources: UAMH 3279, air sampling, Rabat, Morocco, by J. Chabert, from Nicot, Paris as 5216; UAMH 2578, from CBS as (CBS 344.49?) strain von Arx of *Ramularia gei*, possible contaminant in culture

Arthrographis cuboidea (Sacc. et Ellis) Sigler comb. nov.

= Oospora cuboidea Saccardo et Ellis 1882, Michelia 2:576 (Basionym)

= Geotrichum cuboideum (Sacc. et Ellis) Sumstine 1913, Mycologia 5:56 and pl. 83

= Coremiella cuboidea (Sacc. et Ellis) Ciferri et Caretta 1960, Mycopath. et Mycol. Appl. 12(3):249 and Tab. 3

= Geotrichum microsporum Smith 1962, Trans. Brit. mycol. Soc. 45(3):388-389 and Tab. 8, fig. 4

= Briosia microspora (Smith) von Arx 1972, Ant. v. Leeuw. 38(3):293

non Stysanus ulmariae McWeeney 1895

= Coremiella ulmariae (McWeeney) Mason ap. Hughes

History

In 1882 Saccardo and Ellis discovered Oospora cuboidea growing on rotting oak in Newfield, New Jersey and provided a brief description but no figures. In 1913, Sumstine examined the presumed isotype specimen and transferred the species to Geotrichum with a brief description and illustration.

In 1960, Caretta examined the isotype specimen of O.

cuboidea of Ellis (from the NYBG) and proposed a new combination Coremiella cuboidea (Sacc. et Ellis) Cif. et Caretta. Included in his concept of this species were four isolates from human feces, one of which (UAMH 829), received from Caretta in 1960 as Coremiella cuboidea, has been identified as a Trichosporon, possibly T. cutaneum. Indeed, Caretta's figures strongly suggest differences between the four human isolates and O. cuboidea. In placing Coremiella ulmariae in synonymy with O. cuboidea Caretta misinterpreted the manner of arthroconidium formation of the latter which he described as an endogenous process (see also Coremiella).

An examination of the isotype specimen of Oospora cuboidea (Fig. 2G) reveals this fungus to be conspecific with Geotrichum microsporum Smith. However, this species belongs neither in Geotrichum nor Coremiella; therefore, a new combination is proposed in Arthrographis.

Von Arx (1972) transferred G. microsporum to Briosia while simultaneously suggesting that Coremiella cuboidea (Sacc. et Ellis) Cif. et Car. and C. ulmariae (McWeeney) Mason apud Hughes could be conspecific with Briosia ampelophaga Cavara, the type of which he examined. However, Briosia differs from both in forming meristem arthroconidia (Kendrick, 1971, p. 168) in contrast to the fission arthroconidia of Arthrographis and the alternate arthroconidia of Coremiella (see also Briosia, Coremiella).

Description

Colonies on PYE grow rapidly, by 7 days reaching a diameter of 50-60 mm and becoming pale yellow, flocculent and powdery with tufts of sporogenous hyphae over the cellophane membrane. The reverse is yellow. Growth at 37 C is almost as rapid and similar in appearance except that the reverse becomes pink or violet by 14 days.

On cereal agar at 7 days, colonies are 60-70 mm, yellow, with dense, flocculent tufts of hyphae. The reverse at first is yellow. A pink pigment diffusing into the agar later stains the reverse of the colony dark blue. Growth is less rapid at 37 C (25-30 mm in 7 days).

Hyphae septate, hyaline, 2-5um in diameter. Conidiophores are scarcely differentiated, simple, hyaline, branching near the apex to form a tuft of sporogenous hyphae. The sporogenous hypha, 80-150um in length, delimited by a basal septum (Fig. 2H), is unbranched, at first sparingly, then more regularly septate (Fig. 2H), in more or less basipetal succession. The sporogenous hypha forms septae at regular intervals, each interval 3.5-5um wide, which further subdivide into uniform segments, 2-2.5um in width (Fig. 2I). The intervening septae, appearing at first less dense, begin to form before initial septation of the sporogenous hypha is complete (Fig. 3A), and develop randomly. Fission arthroconidia (Fig. 3B), formed by disjunction of the hypha in more or less basipetal succession are square, or rectangular, often wider than long, discoid in end view, smooth, hyaline at first, later yellow, 1.5-2.5um x 2-3.5um.

Habitat and Activities

A. cuboidea has been reported from mine timber (Smith, 1962; Fassatiova, 1971) and from southern yellow pine timber (Chidester, 1940). It causes a pink stain in heartwood and sapwood of pine, birch, cyprus, hemlock, spruce, fir, oak and Douglas fir (Chidester, 1940).

A. cuboidea digests cellophane but does not attack keratin.

Material Examined

From wood: *Oospora cuboidea*, ISOTYPE, oak, Newfield, New Jersey, 1881, by Ellis (3536) from NYBG; UAMH 676, birch post, Chalk River, Ontario by K. Shields, 1956, from Hughes DAOM 64066; UAMH 3101, TYPE, *Geotrichum microsporum*, from rotton mine timber, Johannesburg, South Africa, 1955, received from CMI as 94091;
From mushroom bed: UAMH 3792, by K. Komatsu, 1964, from Tubaki, IFO, as 9190.

Bahusakala Subramanian 1958

Type Species

Bahusakala olivaceonigra (Berk. et Br.) Subramanian 1958,
J. Indian Bot. Soc. 37:61-63
= *Septonema olivaceo-nigrum* Berk. et Br. 1873, J. Linn.
Soc. 14:90

According to the description of Ellis (1971), *Bahusakala* is a dematiaceous Hyphomycete forming fission arthroconidia on simple, irregularly branched conidiophores. Fission arthroconidia are brown, 0, 1 or many septate, delicately furrowed or striate, sometimes rough walled, cylindrical or oblong, truncate or rounded at the corners. The type species, *B. olivaceonigra* occurs on members of the family Liliaceae, including *Agave* and *Yucca*.

Muller, Harr and Sulmont (1969) described another species, the *Bahusakala* state of *Aulographina pinorum* (Desm.) v. Arx et Muller which differed from the type species in having smooth arthroconidia and in growing on *Pinus maritima*. In addition, Muller *et*. *al*. (1969) described and illustrated (their Fig. 1) arthroconidium development occurring within the hyphal wall, that is, endogenously. They noted that the wall of the maturing conidium was difficult to differentiate from the outer wall of the original hypha. From their figures, mature conidia appear to be released from the terminal end of the enveloping hypha or by fracture of the hypha.

A single strain (UAMH 3812, CBS 499.66) isolated from

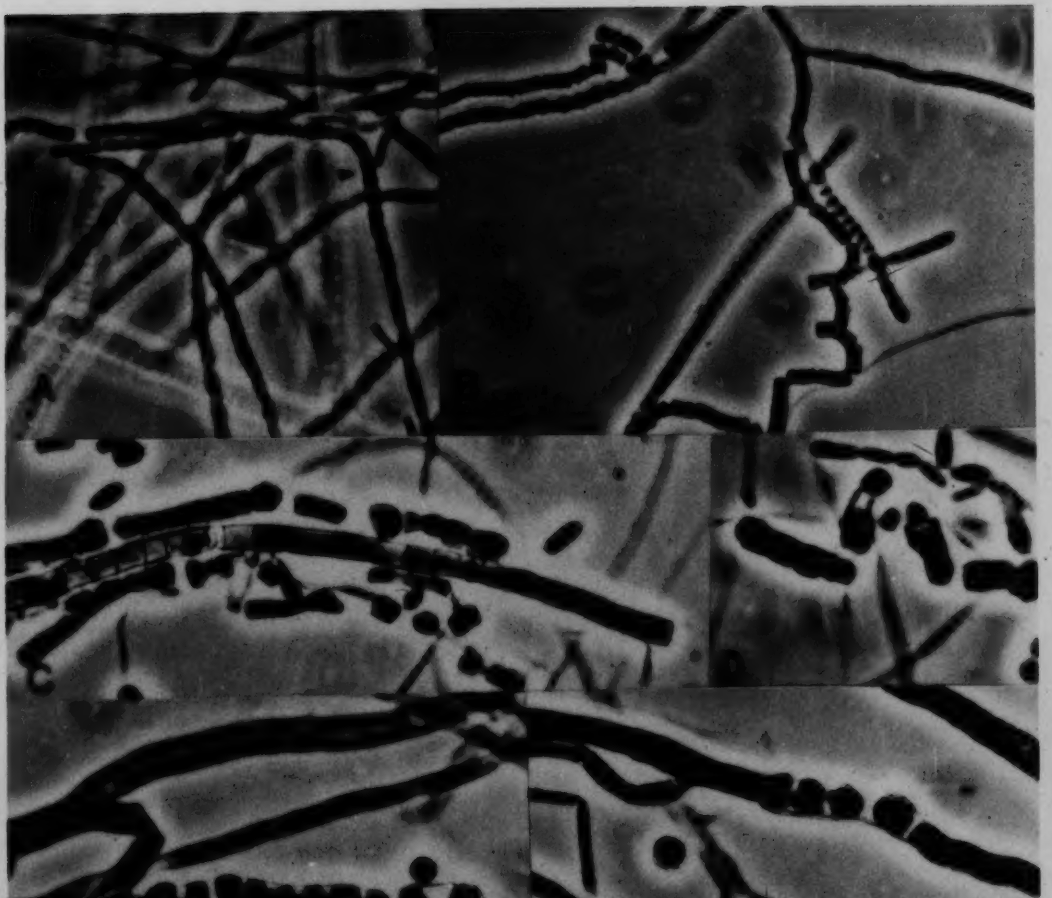
Mangifera indica was received from the CBS as *Bahusakala olivaceonigra*. However, this isolate more closely resembles the *Bahusakala* state of *Aulographina pinorum* rather than *B. olivaceonigra* as described by Ellis (1971).

Arthroconidia of this strain develop on more or less undifferentiated hyphae either terminally or in an intercalary position. Hyphae are pale brown at first, becoming thick walled, yellow brown in color in the fertile segments. The hyphae are broad and sparingly septate, and cytoplasmic contents of some segments appear less dense.

Muller *et*. *al*. (1969) suggested that formation of arthroconidia in *A*. *pinorum* was endogenous. A similar mode of development was observed in UAMH 3812. The fertile segments of the hyphae, at first sparingly septate, cleave into smaller segments (Fig. 3C) and mature arthroconidia are released by dissolution or fracture of the outer wall (Figs. 3E,3F). Remnants of the outer wall are often visible around the released conidia, and conidia occasionally remain connected by the outer wall (Fig. 3D) in groups of 2's or 3's. In addition, arthroconidia form directly by the segmentation and disjunction of segments of the fertile hypha (Fig. 3G). There appears to be no outer wall surrounding these arthroconidia.

Rarely, within a broad hypha in which the cytoplasmic contents are less granular, an intra-hyphal hypha (Buller, 1933) breaking into arthroconidia (Fig. 3H) can be observed.

Figure 3. A-B. Arthrographis cuboidea (A-UAMH 3101; B-676). C-I. Bahusakala olivaceo-nigra (3812). Fig. 3A. Random development of intervening septa. Fig. 3B. Mature fission arthroconidia. Fig. 3C. Septation of undifferentiated fertile hypha. Fig. 3D. Mature conidia, remaining connected in groups of 2's or 3's by sections of the outer hyphal wall. Figs. 3E-3F. Mature arthroconidia released by dissolution or fracture of the outer hyphal wall. Fig. 3G. Fission arthroconidia formed by segmentation of undifferentiated hypha. Fig. 3H. Intrahyphal hypha fragmenting to form arthroconidia. Fig. 3I. Fragmentation of new hyphal branch after fracture of the outer hyphal wall. All x 830, except H, x 2300.


A
C
D
F
H
G
I

A similar situation was recorded by Lowry and Sussman (1966) in a mutant of Neurospora crassa. They observed that the hyphae invaded by intra-hyphal hyphae had sparse cytoplasmic contents and concluded that the invaded hyphae were moribund. They also reported that intra-hyphal hyphae were capable of penetrating the septal plugs of the invaded hypha as well as the outer wall. The frequency of intra-hyphal hyphae in the mutant of N. crassa was attributed to the periodic growth pattern of the isolate.

A similar phenomenon is evident in UAMH 3812. Many hyphae appear moribund, at least in segments. It is possible that the endogenous arthroconidia are actually formed by fission of the intra-hyphal hyphae growing within segments of the original outer wall. As arthroconidia are released from the outer wall, new branches also emerge (Fig. 3I) and this new growth is probably an extension of the intra-hyphal hypha. The extruded endohypha also divides to form arthroconidia (Fig. 3I).

Mature arthroconidia are pale brown, smooth, cylindrical with rounded corners, 0-1 septate, 3-4.5um x 5-10um. No other spore state was observed.

Arthroconidial states of Basidiomycotina

History

In 1889, Brefeld illustrated the conidial states of a number of Hymenomycetes, in which the hyphae divided into short segments called oidia. Hughes (1953) in his experimental classification of the Hyphomycetes discussed the formation of oidia by Basidiomycotina in his Section VII. This group comprised fungi in which the development of conidia occurred by septation and disjunction of simple or branched hyphae.

Brodie (1936) studied oidial development in Collybia velutipes and some other Hymenomycetes. He found that the oidia of Collybia velutipes occurred on both dikaryon and monokaryon mycelia but that clamp connections rarely occurred on the fertile branches of the dikaryon mycelium. He concluded that the oidia of the dikaryon mycelium were haploid.

Nobles (1948) studying the conidial states of a number of wood rotting fungi growing in agar culture, described the oidia of 13 species.

Maxwell (1954) in a study of Thelephoraceae observed that oidia were the most common form of asexual reproduction in the Agaricaceae and Polyporaceae of the Hymenomycetes.

In the UAMH, a number of strains have been accumulated as 'Geotrichum sp.' which appear to be arthroconidial states of Basidiomycotina. Considerable problems arise in trying to place these fungi in form-genera already described. When the arthroconidial states of Basidiomycotina have been more thoroughly studied, some additional genera may be required to accommodate these fungi.

Because the colonial morphology of the arthroconidial states is rather uniform, only one description is provided even though the microscopic morphology is variable. Although a number of isolates have been examined, no attempt was made to include all the known arthroconidial states of Basidiomycotina.

Description

Colonies on PYE (Figs. 4A,4B) grow rapidly (35-62 mm in 7 days and almost filling the petri dish by 14 days) and are white or pale tan, reverse white or yellow. Aerial growth is dry, dense, patchy, matted, woolly or downy, raised, and often more dense on the cellophane than on the exposed medium. When dried, the aerial growth flattens becoming felt-like in texture, turning mottled yellow or tan in color. Most strains produce a diffusing yellow pigment and occasionally copious yellow exudate on the surface. A distinct sweet odor is apparent.

Growth on cereal is slightly more rapid (60-74 mm or filling the petri dish by 7 days) but otherwise similar. The diffusing pigment turns the medium tan in color.

Most strains are incapable of growth at 37 C, but some show slight growth. Most are strongly cellulolytic, markedly weakening the cellophane by 7 days.

Isolates which appear to be Basidiomycotina monokaryons are distinguished by the rapid growth and woolly or felt-like texture of the colonies, the strong odor and cellulolytic activity. On the basis of colonial morphology, the isolates comprise a rather uniform group. However, several variations in arthroconidium development were observed in the strains examined.

a) Group 1 (Strains 448, 507, 511, 1535, 1537, 2098, 2536, 2705, 2769, 2871, 3251, 3436, 3657)

Microscopically, these strains resemble Geotrichum in their arthroconidium development. Fission arthroconidia (Fig. 4D) are formed by septation and disjunction of undifferentiated fertile lateral branches. Arthroconidia are hyaline, barrel shaped or cylindrical, single-celled, measuring 2-4(5.5)um x (2)3-10(15)um. Arthroconidia tend to lie in zig-zag (Fig. 4F) chains, and collapse easily when exposed to air. Thick walled intercalary or terminal chlamydospores (Fig. 4C) are produced by many strains. A single isolate (UAMH 2769) formed clamp connections.

These isolates are not included in Geotrichum since the conidia are dry (see Geotrichum).

b) Group 2 (Strains 3776, 3787)

This group is the conidial state of Phlebia radiata Fr.

Colonies of these strains grow less vigorously, developing less luxurient aerial growth.

The conidial state of Phlebia radiata microscopically resembles Group 1. Arthroconidia are borne in chains on undifferentiated lateral branches which are often curved (Fig. 4E). Fission arthroconidia are hyaline, cylindrical, 2.5-4um x 4-9um. Clamp connections occur in both strains.

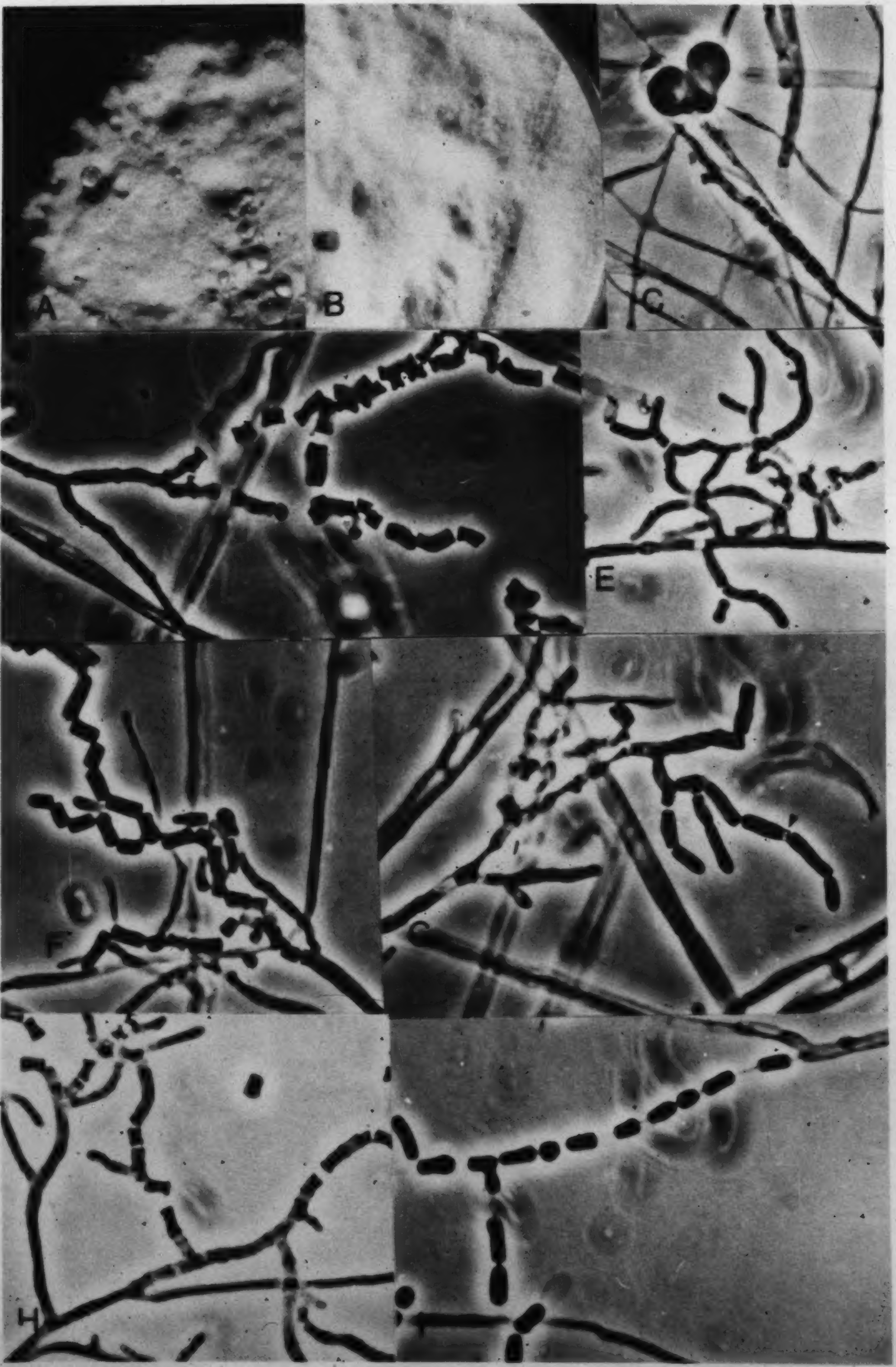
c) Group 3 (Strains 645, 2772, 3412)

Arthroconidium formation in this group differs from groups 1 and 2 in the development of narrow separating cells between maturing arthroconidia (Fig. 4G). The disjunctor cells develop after septation of the fertile hypha (Fig. 4H). Arthroconidium development in this group appears similar to Oidiodendron. The connecting cell is often difficult to detect suggesting that it could be a gelatinous secretion of the maturing arthroconidia similar to the type described for Oidiodendron (see also Oidiodendron).

d) Group 4 (Strains 514, 3796, 3837)

This group contains two strains of Collybia conigena (Pers. ex Fr.) Bres., one of which (UAMH 3837) failed to sporulate.

Figure 4. Arthroconidial states of Basidomycotina. A-B. Colonial morphology (A-UAMH 3251; B-511). C,D,F. Group 1 (C-1537; D-2536; F-1535). E. Group 2 (3776). G-H. Group 3 (G-3412; H-645). I. Group 4 (3796). Figs. 4A-4B. Colonial morphology on PYE after 21 days at 25 C. Fig. 4C. Thick walled chlamydospores. Fig. 4D. Fission arthroconidia borne on undifferentiated hyphae. Fig. 4E. Fission arthroconidia borne on curved lateral branches. Fig. 4F. Mature fission arthroconidia in zig-zag chains. Figs. 4G-4H. Disjunctor cells developing between arthroconidia. Fig. 4I. Mature arthroconidia separated by collapsed disjunctor cells. Colonies x 1.0, others x 830.


A
B
C
E
F
G
H

The oidium development described by Brodie (1936) for Collybia velutipes (Curt. ex Fr.) Quel. is identical with this group. Following cessation of growth of the fertile hypha, the protoplasm of the hypha becomes condensed in segments separated by vacuoles which widen to form a separating cell. Brodie (1936) reported that transverse septa were rarely formed in the fertile hypha and speculated that release of the mature conidium was by dissolution of the outer wall of the separating cell.

The terminal walls of the arthroconidium are apparently formed de novo. Although in some respects resembling Oidiodendron, arthroconidium development in Oidiodendron is preceded by septation of the fertile hypha. The mature arthroconidia of group 4 (Fig. 4I) resemble the alternate arthroconidia of Sporendonema but the arthroconidia of this species are also formed by septation of the fertile hypha. Conidium dehiscence appears to be the same however.

Mature conidia (Fig. 4I) are variable in shape, cylindrical or rounded at the corners, or dumbbell shaped, 2.5-4um x 5.5-13um.

Habitat

Isolated as probable contaminants in clinical material from human and animal sources, and from soil of sheep and horse corrals, and feathers of sparrow, in Alberta, Kentucky, South Carolina, Ohio, Kansas, Georgia, California and Czechoslovakia.

Material Examined

Material of Collybia conigena: UAMH 3796 (CBS 146.29) and UAMH 3837 (CBS 108.13); Material of Phlebia radiata: UAMH 3776 (CBS 278.29) and UAMH 3787 (CBS 285.73); Alberta isolates from clinical specimens: UAMH 448, skin from perianal region, 1955; UAMH 507, sputum, 1956; UAMH 511, toenail, 1956; UAMH 514, blood, 1956; UAMH 645, toes, 1959; UAMH 2536, skin scrapings, canine, 1965; UAMH 3251, urine, 1969; From clinical specimens: UAMH 1535, sputum, from Orr as KCPS 62-5241; UAMH 1537, sputum, from Orr as KCPS 62-5706; UAMH 2705, vitreous humor of eye, Ohio, from J. Schwarz, Univ. of Cincinnati, Ohio; UAMH 3657, Orr-1209; From other substrates: UAMH 2098, California by P. Martin, 1961, as 840; UAMH 2769, sheep pen, Alberta by D. Remington, 1967; UAMH 2772, horse corral, Alberta by D. Remington, 1967; UAMH 2871, soil of broomsedge field, S. Carolina, 1967, from D. Coleman, Savannah River Ecology Laboratory, S. Carolina as G80209; UAMH 3436, feather of house sparrow, Valtice, Czechoslovakia, 1970, by Hubalek, from Orr as 0-3279

Briosia Cavara 1888

Type species

Briosia ampelophaga Cavara 1888, Atti Ist. Bot. Univ. Pavia, ser 2, 1:321-322, Tab. 5; Lindau 1910, in Rabenhorst's Kryptogamen-Flora 1(9):372; Sutton 1973, Mycol. Papers CMI 132:84-85, fig. 40.

non *Briosia cubispora* (Berk. et Curt.) von Arx 1972

= *Cladosporium cubisporum* Berk. et Curt. ap. Berk. 1875

= *Coremiella cubispora* (Berk. et Curt.) Ellis 1971

In the development of the arthroconidia of *Briosia*, meristem arthroconidia of Kendrick (1971, p. 168), septation occurs successively from the apex of the hypha followed by enlargement or expansion *i.e.* meristematic growth of the apical and subsequent segments. Expansion occurs only after delimitation by a septum. Mature arthroconidia are brown, thick-walled, globose or sub-globose or cylindrical and disarticulate by fission, at maturity, 5-7.5um x 6-11um (5-8um in diameter, see Sutton, 1973).

Morris (1963) illustrated meristematic growth occurring before delimitation by a septum in the manner described for *Basipetospora rubra* by Cole and Kendrick (1969) and Kendrick (1971, p. 168).

Von Arx (1972) placed *Coremiella* in synonymy with *Briosia* but *Coremiella* forms alternate arthroconidia rather than meristem arthroconidia. (See also *Arthrographis*.)

Sutton (1973) noted the similarity of conidium development in *Briosia* and *Ojibwaya* Sutton. The latter differed in forming conidiophores from the basal cells of the erect funnel-like wall of the immersed stroma. The conidiophores were not borne on a synnema as in *Briosia*. Sutton (1973) considered *Briosia ampelophaga* to be closely related to *Coremium luteolum* Camara apud Serafim collected from *Vitis* in Portugal. However the lack of type material hindered positive identification.

Habitat

Briosia ampelophaga occurs primarily on leaves of *Vitis* and *Platonia* causing leaf spot, and sometimes on fruits of *Vitis viniferae*. It has been collected in Brazil, Italy, Wisconsin and Illinois.

Material Examined

UAMH 3822, on leaves of *Vitis riparia*, Daneville, Illinois, from DAOM as 137503, collected by Solheim.

Other Species

Briosia azaleae (Peck) Dearness 1941, Mycologia 33:360

= *Periconia azaleae* Peck 1833, Ann. Rep. N.Y. State Mus. 25:93

= *Sporocybe azaleae* (Peck) Saccardo 1886, Syll. Fung. 4:608

Though I have examined no material, Dearness in his description noted few differences from B. ampelophaga. The arthroconidia of B. azaleae however, are smaller, measuring 3-7.5um x 2.75-4.5um. Furthermore, B. ampelophaga occurs commonly on grape leaves whereas B. azaleae has been recovered from bud and twig blight of azalea (Davis, 1939).

Excluded Species

Briosia cystopoides (Bubak et Krieger) v. Arx 1972
= Coremiella cubispora q.v.
Briosia microspora (Smith) v. Arx 1972
= Arthrographis cuboidea q.v.

Chrysosporium Corda 1833

Type Species

Chrysosporium merdarium (Link) Carmichael 1962,
Can. J. Bot. 40:1160 and figs. 30-34
= Sporotrichum merdarium Link 1818, Jahrb. Gewachsk. 1:176
= Chrysosporium corii Corda 1833, Sturm's Deutschl. Flora III (Pilze), Bd. 3, Heft. 13:85

For further synonymy and descriptions of other species of Chrysosporium, refer to Carmichael (1962). Chrysosporium differs from Malbranchea in forming aleurioconidia borne terminally or on short or long lateral branches or directly on the sides of the hyphae. The aleurioconidia of *Chrysosporium* are broader than the diameter of the fertile hypha. Aleurioconidia intergrade with alternate arthroconidia which may predominate in some species.

Other Species

Chrysosporium pannorum (Link) Hughes 1958, Can. J. Bot. 36:749 = *Ovadendron pannorum* q.v.

Coccidioides Stiles 1896

Type Species

Coccidioides immitis Stiles in Rixford and Gilchrist 1896, Johns Hopkins Hospital Report 1:209-269

C. immitis is a human pathogen that occurs in tissue in the form of globose cells which divide internally to produce a few to many endospores. These structures were at one time interpreted as asci and ascospores (see Dodge, 1935, p. 147) but no one has demonstrated karyogamy or meiosis in connection with them. Currently, the endosporulating cells are referred to as 'spherules'.

It seems likely that the spherules represent an unusual adaptation to parasitic growth, with multiplication by endosporulation instead of budding (as in most fungal pathogens) or fission arthroconidia (as in the dermatophytes). Other characters of C. immitis suggest that it may be a heterothallic member of the Gymnoascaceae, whose sexual state has not yet been observed.

In culture, C. immitis grows as a mold and produces arthroconidia typical of the form-genus Malbranchea. A description of the conidial state and further discussion are given under the Malbranchea state of Coccidioides immitis.

Coremiella Bubak et Krieger 1912

Type Species

Coremiella cubispora (Berk. et Curt.) Ellis 1971, in
Dematiaceous Hyphomycetes p. 33, fig. 6
= Cladosporium cubisporum Berk. et Curt. apud
Berk. 1875, in Grevillea 3:107 (Basionym)
= Coremiella cystopoides Bubak et Krieger 1912, Annal.
Mycol. 10:52-53
= Briosia cystopoides (Bubak et Krieger) v. Arx 1972
= Coremiella ulmariae (MacWeeney) Mason apud Hughes 1953,
Can. J. Bot. 31:640, fig. 94
= Stysanus ulmariae MacWeeney 1895, Irish Naturalist
4:277
non Coremiella cuboidea (Sacc. et Ellis) Ciferri et
Caretta 1960

Because of the detailed account provided by Ellis (1971) only a brief description is given here. Arthroconidia (Fig. 5A) are alternate, separated from each other by one or more empty cells, smooth, thick walled, oblong or cubical with a small papilla at each end, brown, 3.5-7um x 4-9(14)um. Mature conidia are liberated by fracture or lysis of the outer hyphal wall of the adjacent empty cell often leaving a frill of outer wall material attached to the conidium. The fertile hyphae often show characteristic dichotomous branching (Bubak, 1912; Hughes, 1953). Conidiophores are loosely aggregated to form a coremium, hemispherical at the tip, rarely observed in culture.

Arnaud (1954) described and illustrated Geotrichella alternata without a Latin diagnosis. Though Kendrick and Carmichael (1973) suggest possible synonymy with Coremiella the status is not clear. Tubaki (in Kobayashi et. al., 1967) described Geotrichella arctica, a fungus bearing considerable resemblance to Coremiella. Unfortunately, it was not possible to obtain the type specimen for study.

The alternate arthroconidia of Coremiella distinguish this form-genus from dematiaceous fungi forming arthroconidia by fission such as Scytalidium, Briosia and Bahusakala.

In its conidium development Coremiella resembles both Sporendonema and Malbranchea but differs from both in having darkly pigmented cell walls and also from the latter in the diameter of the fertile hyphae. The hyphae and arthroconidia of Coremiella are much wider 3.5-7um in diameter, whereas those of Malbranchea rarely exceed 3.5um.

Habitat and Activities

This species has been recorded on senescent and living plant material and appears to have a worldwide distribution. Lucas, Carvalho and Barreiro (1974) report an incidence of soft rot in pears caused by C. cubispora.

C. cubispora digests cellophane but does not attack keratin. It grows vigorously at 30 C but fails to grow at 37 C.

On agar the fungus releases a pigment which appears grey or brown on cereal agar or yellow on PYE.

Material Examined

UAMH 1165, photomicrograph of a DAOM specimen 35160, from Ranunculus leaf, England, determined by E.W. Mason; UAMH 1513, from Picea abies, Denmark by Mason 1949, from CMI as 36938; UAMH 3793, from stump of Lindera umbellata Japan by M. Ichinoe, 1966, received from Tubaki, IFO, Japan as 8862 (NHL 4583).

Geotrichum Link 1809

Type Species

Geotrichum candidum Link 1809, Berlin Magazin 3:17; Persoon 1822, Mycologia Europaea 1:26; Carmichael 1957, Mycologia 49(6):820-830

For full synonymy refer to Carmichael (1957)

Perfect state:

Endomyces geotrichum Butler et Petersen 1972, Mycologia 64:367

The form-genus Geotrichum is distinguished by formation of hyaline arthroconidia in chains by segmentation of undifferentiated hyphae; conidiophores are absent. Arthroconidia develop by septation and disjunction at a double septum of lateral branches or the broader vegetative hyphae which may branch dichotomously. Arthroconidia are thin-walled, smooth, cylindrical or ellipsoidal or oblong, sometimes becoming subglobose.

The developmental sequence of arthroconidium formation in G. candidum and the Geotrichum state of Endomyces magnusii has been recorded by time lapse photography (Cole and Kendrick, 1969).

Numerous species have been described in Geotrichum making the taxonomy of the genus complicated and confused. For Geotrichum candidum alone, a species demonstrating considerable variation in culture, Carmichael (1957) lists over 50 synonyms.

Furthermore, characters of many species included in Geotrichum are contrary to those attributed to the type species. For this reason, the following should be excluded from Geotrichum: dematiaceous species (see Scytalidium); fungi with differentiated conidiophores (see Arthrographis and Oidiodendron); species lacking fission arthroconidia (see Coremiella, Sporendonema, Malbranchea and Oidiodendron), and fungi forming blastoconidia as well as fission arthroconidia (see Trichosporon, Moniliella). Many species previously described in Geotrichum can be referred to one of these form-genera.

However, a number of difficult problems remain. In culture, the type species, G. candidum, appears dry, hairy or powdery, but the texture is slimy. This yeast-like texture is also characteristic of some other species of Geotrichum. If this yeast-like form of growth is a valid generic character, then fungi having dry-spored fission arthroconidia should be excluded. However, in order to exclude closely related fungi from Geotrichum, a suitable form-genus must be available for admission. As yet, no other form-genus has been proposed to accommodate non yeast-like fungi developing hyaline fission arthroconidia on undifferentiated hyphae. (See also arthroconidial states of Basidiomycotina.)

An additional problem, in assigning fungi to Geotrichum is defining the degree of specialization of the conidiophore. According to the definition accepted by the Kananaskis Conference on Fungi Imperfecti (Kendrick, 1971, p. 224-228), the hypha of Geotrichum which fragments to form arthroconidia is a simple conidiophore, 'micronematous' of Ellis (1971). However, this fertile hypha is indistinguishable from the vegetative hypha before the process of conversion begins (Cole and Kendrick, 1969). As well, intercalary arthroconidia form in the broader vegetative hyphae (Carmichael, 1957). It is often difficult, therefore, to differentiate between an undifferentiated fertile hypha i.e. 'micronematous' conidiophore and a slightly differentiated i.e. 'semi-macronematous' (Ellis, 1971) conidiophore. Species with differentiated conidiophores are excluded from Geotrichum (see Arthrographis).

Without access to herbarium specimens or cultures, only a limited number of Geotrichum species could be reviewed. Where possible, the status of some has been determined from the available literature, but the study is by no means inclusive.

Species

Geotrichum amycelicum Redaelli et Ciferri 1935, Archiv. fur Mikrobiologie 6:60

Von Arx (1972) suggested that this species, as well as

G. gracile, G. vanryiae and G. hirtum may belong in Trichosporon.

Geotrichum fragrans (Berkhout) Morenz 1960, Taxonomie und medizinische Bedeutung der zur Gattung Geotrichum Link gehorenden Arten p. 178 [= Oospora fragrans Berkh.]

Geotrichum klebahnii (Stantz) Morenz [as 'klebhani'], ibid, p. 180 [= Oospora klebahni Stantz]

Geotrichum gracile (Weigmann et Wolff) Windisch 1952, Beitr. Biol. Pflanzen 29:157

?= Trichosporon fide von Arx (1972)

Geotrichum hirtum Windisch 1952, Beitr. Biol. Pfanzen 29:157

?= Trichosporon fide von Arx (1972)

Geotrichum state of Endomyces magnusii Ludwig 1886, Ber. Deut. Bot. Ges. 4:17

For a description, refer to von Arx (1972).

Geotrichum vanriji Saez 1964, Bull. mens. Soc. linn. Lyon 33(7):266

Von Arx (1972) suggested G. vanryiae Saez is closely related to *G. gracile* and *G. amycelicum* and all may belong in *Trichosporon*.

Excluded Species

Geotrichum cinnamoneum (Libert) Saccardo 1886, Michelia 2:636

Though I have not seen material, Saccardo's description and the study of Quinta (1968) suggests that this species may be identical to *Wallemia sebi* (Fr.) von Arx.

Geotrichum cuboideum (Sacc. et Ellis) Sumstine ≡ *Arthrographis cuboidea* q.v.

Geotrichum dulcitum (Berkh.) Windisch 1952, Beitr. Biol. Pflanz. 29:156
= *Protendomycopsis domschii* Windisch 1965, Beitr. Biol. Pflanz. 41:337 = *Protendomycopsis dulcita* (Berkh.) Gams et Domsch 1969, Nova Hedwigia 18:20

Although proposing a new combination, Gams and Domsch treat this species under *Trichosporon cutaneum*.

Geotrichum flavo-brunneum Miller *et al*. 1957 ≡ *Scytalidium flavo-brunneum* q.v.

Geotrichum microsporum Smith 1962 ≡ *Arthrographis cuboidea* q.v.

Geotrichum purpurascens (Bon.) Sacc. 1886 = Sporendonema purpurascens q.v.

Geotrichum roseum Grove 1886 ?= Sporendonema purpurascens q.v.

Geotrichum rotundatum (Cast.) Cif. et Red. 1935, Arch. Mikrobiol. 6:59 = Trichosporon cutaneum fide Lodder and Kreger van Rij according to Saez (1964)

Geotrichum rugosum (Cast.) Dodge 1935, Medical Mycology p. 219 = Trichosporon cutaneum fide Lodder and Kreger van Rij according to Saez (1964).

Geotrichum suaveolens (Lindner) Cif. apud Diddens et Lodder 1942, in Die anaskosporogen Hefen II:271 = Moniliella suaveolens (Lindner) von Arx 1972

Malbranchea Saccardo 1882

See Part II

Oidiodendron Robak 1932

Perfect States: Myxotrichum Kunze, Byssoascus von Arx

Lectotype Species

Oidiodendron tenuissimum (Peck) Hughes 1958, Can. J. Bot. 36:790

= Periconia tenuissima Peck 1893, N. Y. State Museum Report 46:113 (Basionym)

= Oidiodendron fuscum Robak 1932, Saetryk av. Nyt. Mag. Naturvidensk 71:251

This wood and soil fungus forms arthroconidia on branched or unbranched hyaline fertile hyphae borne at the apex of a pigmented conidiophore. Occasionally conidiophore production is suppressed with arthroconidia forming directly on undifferentiated fertile hyphae.

The exact mode of development of arthroconidia is not completely understood. Barron (1962) in his monograph of nine species reported that arthroconidia were formed either endogenously, remaining connected within the original outer hyphal wall until maturity, or more commonly, formed directly by segmentation of the hypha with each developing conidium drawing apart slightly but remaining connected by a gelatinous secretion between maturing conidia.

Cole and Kendrick (1969) in a time-lapse study of O. truncatum concurred with this latter view. They found that initial septation, possibly by double septa, was followed by rounding up and drawing apart of the immature arthroconidia leaving a clear area between adjacent conidia. The clear areas, termed connectives, were often traversed by a septum. Cole and Kendrick (1969) agreed with Barron (1962) that the connectives were either remnants of the outer hyphal wall left after endogenous formation of conidia, or more probably, that they were gelatinous secretions from the maturing conidia. The presence of a septum within the connectives suggested that new terminal end walls distinct from the original septum were formed by the maturing arthroconidium. In a further discussion, Kendrick (1971, p. 162) designated this type of arthroconidium development as type 2.

Arthroconidia of Oidiodendron, separated from each other by gelatinous connectives are distinct from the fission arthroconidia of Geotrichum and Arthrographis and the alternate arthroconidia of Malbranchea and Ovadendron. Oidiodendron is further distinguished by its pigmented conidiophores.

For a discussion of the species of Oidiodendron, the reader is referred to Barron (1961, 1962), Morrall (1968), Cole and Kendrick (1969), Kobayasi et. al. (1969), Kiffer, Mangenot and Reisinger (1969) and Tokumasu (1973). In addition, Oidiodendron conidial states have been described for Myxotrichum cancellatum [= Toxotrichum cancellatum] (Orr and Kuehn, 1964a; Apinis, 1964), Arachniotus flavoluteus (Muller and Pacha-Aue, 1968) and Byssoascus striatosporus [=

Arachniotus striatosporus] (Barron and Booth, 1966; von Arx, 1971). However, the *Oidiodendron* conidial state of *A. flavoluteus* reported by Muller and Pacha-Aue (1968) appears doubtful since my examination of the type strain of *A. flavoluteus* (UAMH 3531, CBS 627.71, NRRL 1243) reveals no conidial state. In addition, neither Kuehn and Orr (1959), Udagawa (1963), nor von Arx (1971) have reported an asexual state for this species.

Oidiodendron state of *Myxotrichum striatosporus*

Perfect State:

Myxotrichum striatosporus (Barron and Booth) Sigler comb. nov.

≡ *Arachniotus striatosporus* Barron and Booth 1966, Can. J. Bot. 44:1060 (Basionym)

≡ *Byssoascus striatosporus* as '*striatisporus*' (Barron and Booth) von Arx 1971, Persoonia 6(3):377

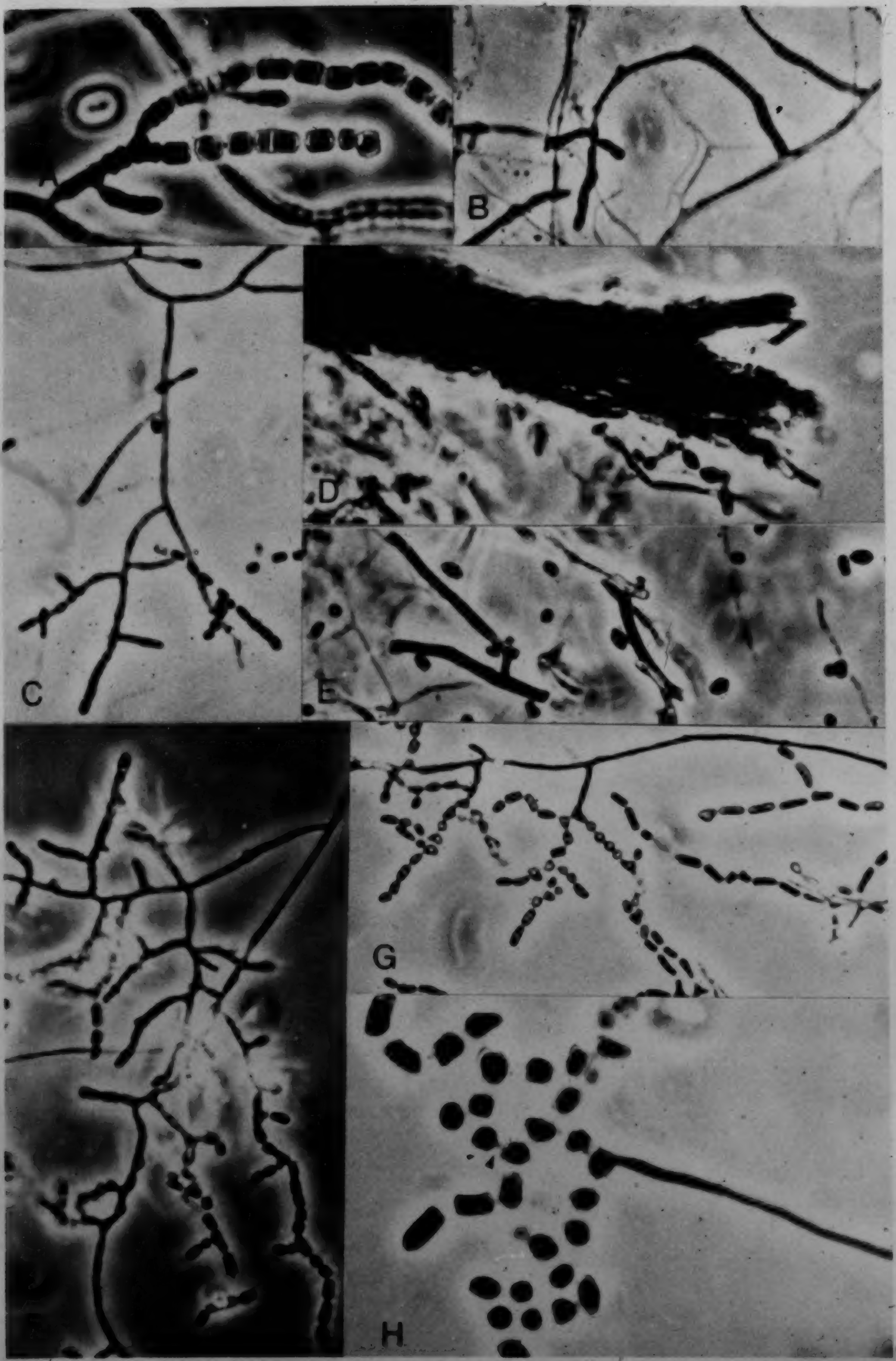
Barron and Booth (1966) described this species in *Arachniotus* having white confluent cleistothecia composed of narrow, hyaline peridial hyphae and fusiform, striate yellow ascospores. In their preliminary discussion, however, they noted that darkly pigmented hyphae occurred in association with the cleistothecia, but did not include their description in the Latin diagnosis. Von Arx (1971) removed the species from *Arachniotus* and proposed a new genus, *Byssoascus*, because of the fusiform, striate ascospores.

There appears to be little justification for creating a new genus for this fungus. On the basis of ascospore morphology alone, this species does not differ from species of Myxotrichum which have ellipsoidal or fusiform ascospores. Ascospores of some species, such as M. deflexum and M. chartarum (Orr, Kuehn and Plunkett, 1963b; Apinis, 1964; Visset, 1974) also have longitudinal furrows which are clearly visible when the ascospore is seen in polar view at high magnification. The ascospores of M. striatosporus are more definitely striate but this character would not exclude the species from Myxotrichum.

The primary reason for the removal to Byssoascus would seem to be the nature of the cleistothecium, composed of thin walled narrow hyphae. Examination of the type strain (UAMH 3572 and 3758, CBS 642.66, CMI 115998) revealed that production of ascospores was consistently associated with the formation of dark brown, thick walled, smooth hyphae, often aggregated into ropes (Fig. 5D). When cultured on cereal agar, the colony is dense and the ascospores are produced beneath the surface among the thick walled hyphae. No discrete cleistothecium or peridial walls were seen. Other Myxotrichum species have been described in which the cleistothecia coalesce and do not detach readily from the vegetative hyphae (see Malbranchea circinata, Myxotrichum setosum).

The transfer to Myxotrichum is proposed for several

Figure 5. A. Coremiella cubispora (UAMH 3793). B-E. Oidiodendron state of Myxotrichum striatosporus (B,D,E,-3572; C-3578). F-H. Oidiodendron state of Myxotrichum setosum (3835). Fig. 5A. Alternate arthroconidia borne on dichotomously branched hyphae. Fig. 5B. Arthroconidia borne on pigmented conidiophore. Fig. 5C. Arthroconidia borne on hyaline conidiophore. Fig. 5D. Dark brown 'peridial' hyphae aggregated into ropes, and fusiform striate ascospores. Fig. 5E. Ascospores and segments of peridial hyphae showing blunt tipped branches. Figs. 5F-5G. Arthroconidia borne on hyaline conidiophores. Fig. 5H. Septum (arrow) traversing connective between adjacent arthroconidia. All x 830, except H, x 2300.


B
C
D
E
G
H

reasons. First, the ascospore shape and surface, the Oidiodendron conidial state and the cellulolytic activity of the fungus are consistent with other species of Myxotrichum. In addition, the dark brown, thick walled, coalescing hyphae (Fig. 5D) are branched and often have blunt tips where the terminal portion has broken off (Fig. 5E). This severance of the tip of branches is seen frequently in species of Myxotrichum and is quite characteristic for the genus. Finally, the similarity of M. striatosporus to M. setosum suggests these two species should be retained in the same genus.

The Oidiodendron state of M. striatosporus is distinct and closely resembles the O. state of M. setosum. In culture on cereal agar, the conidiophores of M. striatosporus are mostly hyaline (Fig. 5C) and narrow in diameter, rarely becoming pigmented at the base (Fig. 5B). Often arthroconidia are formed directly on undifferentiated hyphae. Arthroconidia are smooth or slightly rough walled, olive green, barrel shaped 1.5-2.5um x 1.5-3.5um. Barron and Booth (1966) noted that the barrel shaped arthroconidia differed from arthroconidia of other species which were mostly ovoid, globose or cylindric.

In addition to the microscopic morphology, the colonial appearance of M. striatosporus and M. setosum is very similar. M. striatosporus grows slowly on both PYE and cereal. On cereal, the colony is 22 mm in diameter at 14 days, flat, slightly zonate, velvety, dark olive green with characteristic bright yellow margin, reverse brown. On PYE, the colony is pale olive green adhering poorly to the cellophane and lifting up at the margin.

Oidiodendron state of Myxotrichum setosum (Eidam) Orr and Plunkett, in Orr et. al. 1963b, Can. J. Bot. 41:1457-1480

?= Oidium microspermum Berkeley et Broome 1873, in Ann. Mag. Nat. Hist. 4, ser. II, 346

= Oospora microsperma (Berk. et Br.) Saccardo et Voglino 1886, Sylloge Fungorum 4:22

History

Berkeley and Broome (1873) described Oidium microspermum from bark of Scotch fir with a brief description but no illustration. Saccardo and Voglino (in Saccardo, 1886) transferred O. microspermum to Oospora based on Berkeley and Broome's description. Lindau (1907) described the fungus from an exsiccati specimen, Rabenhorst's Fungi europa 1577, from Lonicera xylosteum.

Since I have seen neither illustrations nor the type specimen of Oidium microspermum no new combination is proposed for the imperfect state. However, both specimens examined were identified by DAOM (37243 and 144716) as

Oidium microspermum. Therefore, it is listed as a probable synonym of the Oidiodendron state of Myxotrichum setosum.

According to Dale (1903), the perfect state, Gymnoascus setosus was first described by Eidam in 1882 at a meeting of the Schleisische Gesellschaft fur vaterlandische Cultur. The original description (Eidam, 1882) based on an isolate from a wasp's nest apparently was brief and lacked illustrations.

In 1902, Massee and Salmon in a study of coprophilous fungi, recovered G. setosus on a bee's nest in England. They provided a description and an illustration of their isolate (Figs. 6D,6E). Massee and Salmon noted the distinctive white centrum of the ascocarp.

Dale (1903) studied the isolate of Massee and Salmon in agar culture. However, the isolate failed to produce the sexual state in culture even after growth on a variety of media over a period of eighteen months. Dale reported a conidial state formed from the germinating ascospores, reproducing by budding when grown on 2% beer wort agar. However, after prolonged growth, vegetative hyphae formed which branched and bore conidia at the nodes. Dale noted the resemblance to conidium development in Verticillium.

DeLamater (1937) comparing G. setosus with Eidamella spinosa [= Myxotrichum deflexum] concluded the two species were distinct and disagreed with Dodge's (1935) placement of

E. spinosa into synonymy with *G. setosus*. Apinis (1964) concurred with DeLamater.

Orr and Plunkett (in Orr *et. al*., 1963b) proposed a new combination *Myxotrichum setosum* (Eidam) based on the description and figures of Massee and Salmon (1902) and Dale (1903) and the original description of Eidam (1882). Orr and Plunkett were unable to find a type specimen nor any recent isolates of *G. setosus*. Despite the detailed account of Dale (1903) of the conidial state, Orr and Plunkett reported the asexual state to be unknown.

Apinis (1964) examined the original drawings of Massee (NY) of *M. setosum* as well as two specimens from bee hives. In his description, Apinis (1964) described the conidial state as oidia, 2 - 3um in diameter.

Although an *Oidiodendron* state has not previously been reported for *M. setosum* it may have been overlooked. Conidiophore development is weak and conidiophores remain unpigmented. Arthroconidia often develop on undifferentiated hyphae. These are probably the oidia described by Apinis (1964). The conidial state of *M. setosum* described by Dale (1903) is more difficult to interpret, though it is possible she was either working with a mixed culture, or misinterpreting the mode of conidium development as blastospores rather than arthrospores. The fact that she failed to find the perfect state in culture is not surprising since this species is psychrophilic. Its common isolation from old nests of bees or wasps suggests that the sexual state is formed after an overwintering period.

Description

The colony on PYE at 25 C is slow growing, 17 mm in diameter at 21 days, pale olive, reverse tan, velvety, adhering poorly to the cellophane with the margin of the colony lifting up and becoming undulate and the center raised.

On cereal, the colony is flatter, stretching to 22 mm at 21 days with slightly raised center, powdery, dry and cracked, olive green in color with 1-2 mm wide pale yellow margin, buff reverse.

This species is psychrophilic, growing and forming the perfect state at 8 C.

Vegetative hyphae are hyaline, septate, narrow. Conidiophores (Figs. 5F,5G) are hyaline, narrow, 1-1.5um in diameter, 30-140um in length, branching at the apex to form fertile hyphae of the same diameter. Arthroconidia develop in more or less basipetal succession on the fertile branches (Fig. 5F) or on undifferentiated hyphae. Arthroconidia, becoming slightly rounded, remain linked by connectives often traversed by a septum (Fig. 5H). Arthroconidia are olive colored with thickened walls (Fig. 5H), smooth, mostly cylindrical, sometimes subglobose or ovoid, 1.5-2um x 3-5um.

Homothallic. Cleistothecia confluent, not discrete. Peridial hyphae (Fig. 6A) not anastomosed, composed of dense, dark brown, septate, thick walled hyphae terminating in long spines (Fis. 6A,6D) bearing two or three short lateral spines, often opposite to each other (Fig. 6D). Ascomatal initials are coiled (Fig. 6B); asci are hyaline, evanescent, subglobose, 6-7um in diameter. Ascospores (Figs. 6C,6E,6F) are pale green at maturity, smooth, fusiform or navicular in shape, with one face flattened, 1.5-2um x 3.5-6.0um.

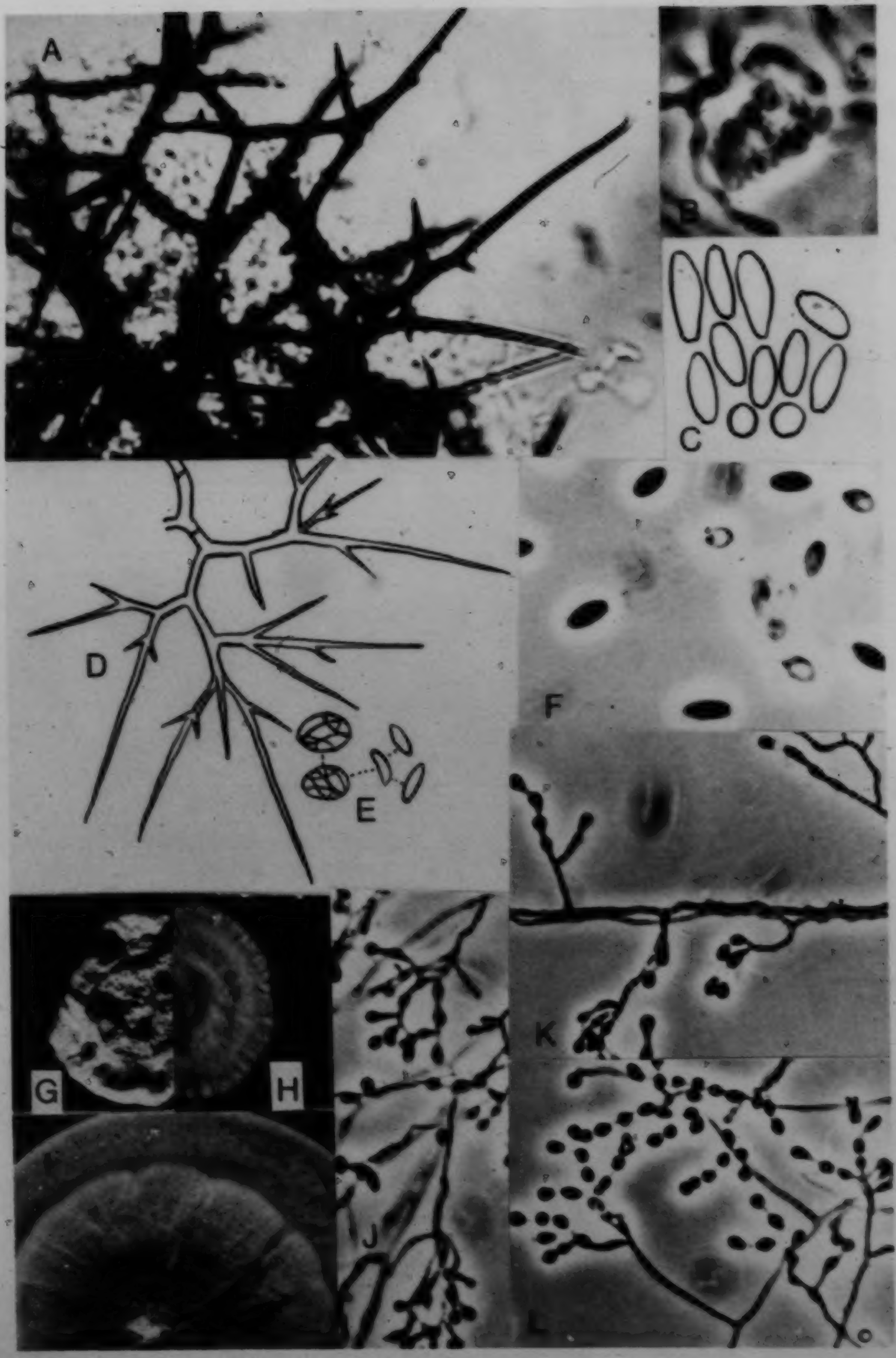
Discussion

The description and figures (Figs. 6D,6E) of Massee and Salmon (1902) correspond well with the fungus described here. In their description, they noted that the centrum containing asci remained permanently white. In young cultures, this is true, but as the ascospores mature, the centrum becomes greenish yellow in color.

The characteristic feature of M. setosum noted by Dale (1903) was the sharply pointed branched spines of the peridial hyphae which did not anastomose to form a discrete cleistothecium. The dark brown color of the peridial hyphae and the fusiform shape of the ascospores suggest that this species is correctly placed in Myxotrichum.

Figure 6. A-F. Myxotrichum setosum (A-C,F-UAMH 3835). G-L. Ovadendron asperulatum (G-J,L-183; K-2815). Fig. 6A. Coalescing dark brown sharply pointed spines of peridial hyphae, x 830 BF. Fig. 6B. Coiled ascomatal initials, x 2300. Fig. 6C. Ascospores, x 2700. Fig. 6D-6E. Illustration of Massee and Salmon (1902) showing peridial hyphae (x400) and ascospores (x 1000). Fig. 6F. Ascospores, x 2300. Figs. 6G-6I. Colonial morphology after 21 days at 25 C, x 1.0. G and H on PYE, I on cereal. Fig. 6J. Verticillately branched conidiophores bearing chains of arthroconidia, x 830. Figs. 6K-6L. Chains of arthroconidia, x 830.

5


A
B
C
D
E
F
G
H
J
K
L

Placement of the conidial state in Oidiodendron is most suitable for the present. Although the conidiophores are hyaline, the development of arthroconidia cannot be differentiated from other species of Oidiodendron, especially the O. state of M. striatosporus. However, if other similar fungi are discovered which lack the characteristic pigmented conidiophores of Oidiodendron then a new form genus could be considered to accomodate these fungi. Indeed, the conidial state of the ascomycete, Cookeina sulcipes (Berk.) Kuntze, was grown in culture and reported by Paden (1975) to form arthroconidia separated by connectives similar to the type described for Oidiodendron truncatum by Kendrick (1971, p. 162). Paden (1975) did not describe the nature of the conidiophore.

Habitat and Activities

Recorded from wood of Picea glauca, soil of Alpine regosol, Alberta, nests of wasps and bees, and honey-comb of bees, England and Germany.

This species is neither keratinolytic nor cellulolytic.

Material Examined

UAMH 1174, photomicrograph of DAOM 37243, from Picea glauca; UAMH 3835, washed soil particles from Alpine regosol, Kananaskis, Alberta, between 1968 and 1972, received from DAOM as 144716 (Bissett, JB 922).

Oidium Link 1809 = *Sporotrichum* Link 1809

Type Species

Oidium aureum (Pers.) Link 1809, Mag. Ges. Naturf. Freunde Berlin 3:18

= *Trichoderma aureum* Persoon 1801, Syn. Meth. Fung. p. 232

= *Sporotrichum aureum* Link 1809, Mag. Ges. Naturf. Freunde Berlin 3:13

Link proposed *O. aureum* for a specimen which he believed to be identical with *Trichoderma aureum* Persoon. However, the fungus which Link identified as *T. aureum* Persoon was in fact *T. dubium* of Persoon. Link, in the same paper, described several species of *Sporotrichum*, one of which was *S. aureum*, and Hughes (1958) recognized that *S. aureum* was identical with Persoon's *T. aureum*. Hughes therefore considered *Oidium* to be a synonym of *Sporotrichum*.

Although Hughes (1958) and others (Carmichael, 1962; von Arx, 1970; Ellis, 1971; Kendrick and Carmichael, 1973) have rejected *Oidium*, the name is still widely used, both for lignicolous Hyphomycetes which have their perfect state in *Botryobasidium* (Pouzar and Jechova, 1967; Holubova-Jechova, 1969; Eriksson and Ryvarden, 1973), and for conidial states of Erysiphales. Kendrick and Carmichael

(1973) referred species of the first group to Alysidium, Olpitrichum and Acladium and species of the latter group to Acrosporium.

Recently, Weresub (1973) discussed the controversy over Oidium and agreed with Hughes' invalidation of Oidium. However, because of the widespread use of the name by both plant pathologists, for the conidial states of Erysiphales, and basidiomycete taxonomists for the conidial states of Botryobasidium, she proposed that a decision be made for conservation of Oidium for one or other group. However, she recommended that if both proposals were rejected, the use of Oidium should be discontinued.

Other Species

Oidium microspermum Berkeley et Broome 1873, in
Ann. Mag. Nat. Hist., ser. II, 4:346
?= Oidiodendron state of Myxotrichum setosum q.v.

Oospora Wallroth 1833

Type Species

Eleven original species, including the type species of four other genera were included in Oospora by Wallroth (Fl. Crypt. Germ. 2:182, 1833)

Numerous species have since been added to Oospora, a nomen illegitimum, according to Hughes (1958). Some Malbranchea species may have been described previously in Oospora, but in most cases, the descriptions, often lacking illustrations, are inadequate for an accurate comparison. Examination of the type specimen, if still available, would be required to determine the correct relationships.

Species

Oospora crustacea Saccardo 1882, Michelia 2:545 ?= Sporendonema casei q.v.

Oospora cuboidea Saccardo et Ellis 1882, Michelia 2:576 ≡ Arthrographis cuboidea q.v.

Oospora microsperma (Berk. et Br.) Saccardo et Voglino 1886, Syll. Fung. 4:22 ?= Oidiodendron state of Myxotrichum setosum q.v.

Ovadendron Sigler et Carmichael gen. nov.

Diagnosis

Vegetative hyphae narrow, hyaline, septate. Conidiophores, if present, are narrow, hyaline, branched verticillately at the apex, at an acute angle. The fertile branches are narrow, at first sparingly, then more regularly septate. Aleurioconidia, formed terminally or laterally on short pedicels, intergrade with alternate arthroconidia. Alternate arthroconidia, broader in diameter than the fertile hypha, develop in long chains and predominate in some species. Mature conidia, released by lysis of intervening segments are smooth or roughened, hyaline or yellow, barrel shaped, cuneiform, subglobose or pyriform. Type species: *Ovadendron asperulatum* Sigler et Carmichael sp. nov.

Discussion

Ovadendron differs from *Malbranchea* in forming arthroconidia which are broader than the diameter of the fertile hypha. The conidiophores of *Ovadendron* distinguish this genus from *Chrysosporium* in which aleurioconidia form directly on the sides of the hypha or on short pedicels, and rarely develop in chains of more than two or three conidia.

Ovadendron asperulatum Sigler et Carmichael sp. nov.

Description

Colonies on PYE (Fig. 6G) growing moderately rapidly (35-39 mm in 21 days) are first pale pink, flat and cottony, becoming vivid mustard yellow, with pink and white patches at the periphery, powdery, reverse tan. The colony adheres poorly to the cellophane, lifting in the center with few radial folds, and curling up at the margin with new growth appearing below. Poorly sporulating colonies (Fig. 6H) are flatter, pale yellow in color with hairy or bristly surface.

On cereal, colonies (Fig. 6I) grow faster (55 mm in 21 days) and are flat, with outward radiating folds, at first white then mustard yellow, reverse the same, powdery. As sporulation occurs, the center (Fig. 6I) becomes flatter than the outer periphery. A brown diffusing pigment appears below the colony by 14 days.

Growth is poor at 30 C and no growth occurs at 37 C. On oatmeal agar at 18 C and 25 C a dark brown pigment diffuses into the agar.

The vegetative hyphae are hyaline or yellow, narrow, septate. Conidiophores are narrow, 0.5-1.0um in diameter, 20-150um in length, hyaline, sometimes branching along the length, verticillately near the apex (Fig. 6J). Fertile hyphae are narrow, 0.5-1.0um in diameter, at first sparingly then more regularly septate, with concentration of cytoplasm in alternate segments. Arthroconidia (Figs. 6K,6L) become thick walled and increase in volume, maturing in long chains in more or less basipetal succession. Mature arthroconida (Fig. 6L), released by lysis of the intervening empty cell, are yellow, slightly roughened, barrel shaped or cuneiform if terminal, 1.5-2.5(3)um x 2.5-4.5(5)um.

Holotype: soil, Harvard Forest, Massachusetts, by F. Raymond (II-1-9), UAMH 183

Habitat and Activities

Ovadendron asperulatum has been recorded from soil in Massachusetts, Ontario and Costa Rica.

It is strongly cellulolytic but does not attack keratin.

Material Examined

UAMH 182, soil, Harvard Forest, Mass., by F. Raymond, Farlow Herbarium as III-4-1; UAMH 183, TYPE, soil, Harvard Forest, Mass., by F. Raymond, as II-1-9; UAMH 2169, Puerto Vieho, Costa Rica, from G.L. Barron, Univ. of Guelph as 10258; UAMH 2815, white pine soil, St. William, Ontario, by G. H. Bhatt, 1967, as U.W. 316.

Ovadendron sulphurea-ochracea (v. Beyma) Sigler comb. nov.

≡ Oospora sulphurea-ochracea van Beyma thoe Kingma 1933, Zentralbl. f. Bakter. u. Parasitenkde, 2 Abt., 88:134 (Basionym)

Description

The colony grows moderately rapidly (30 mm in 14 days) and is white, reverse tan, downy in the center and slightly raised with outer glabrous margin. On cereal, the colony is flat (35 mm in diameter at 14 days), white, reverse tan, floccose.

Vegetative hyphae are hyaline, septate, narrow. Fertile hyphae arise as narrow, 0.5-1.0um in diameter, short, coiled, lateral branches (Figs. 7A,7B) becoming regularly septate, with concentration of cytoplasm in alternate segments. The arthroconidia become thick walled, and increase in volume, maturing in more or less basipetal succession. Released by dissolution of the alternate empty segments, arthroconidia are barrel shaped, hyaline, smooth 2-2.5um x 2.5-4um.

Habitat and Activities

The original isolate of van Beyma was from sputum, Holland.

O. sulphurea-ochracea is keratinolytic, producing moderate digestion and penetration of hairs by single hyphae. Cellophane is not attacked.

Material Examined

UAMH 181, ? TYPE strain, from CBS as strain van Beyma received in 1954, and as CBS 233.32 received in 1975.

Ovadendron pannorum (Link) Sigler et Carmichael comb. nov.

= Sporotrichum pannorum Link 1824, Linn. Spec. Plant. IV, 6(1):13 (Basionym)

= Chrysosporium pannorum (Link) Hughes 1958,
Can. J. Bot. 36:749
= Geomyces vinaceus Dal Vesco 1957, Allionia 3:14

Perfect State:
Pseudogymnoascus roseus Raillo 1929, Zentralbl. Bakt. Parasitenkde, Abt. 2, 78:520, fig. 2
= Gymnoascus rhousiogongylinus Wener and Cain 1970, Can. J. Bot. 48:325

History

For full synonymy and description of O. pannorum refer to Carmichael (1962). Though we have not seen the description of Geomyces vinaceus, Samson (1972) stated that the Chrysosporium conidial state of P. roseus was described as Geomyces vinaceus by Dal Vesco. Also, our strain (UAMH 1643) received from H. H. Kuehn as G. vinaceus Dal Vesco is O. pannorum.

Description

O. pannorum is distinguished by narrow, 0.5-1.0um in diameter, hyaline, 10-100um in length, conidiophores branching verticillately near the apex at an acute angle (Figs. 7C,7D). Aleurioconidia formed terminally or laterally on short pedicels intergrade with intercalary arthroconidia (Fig. 7D). Mature conidia are cuneiform, subglobose or pyriform or barrel shaped if intercalary, hyaline, smooth or roughened, 2-4um x 2-5um, mostly 2 x 3um.

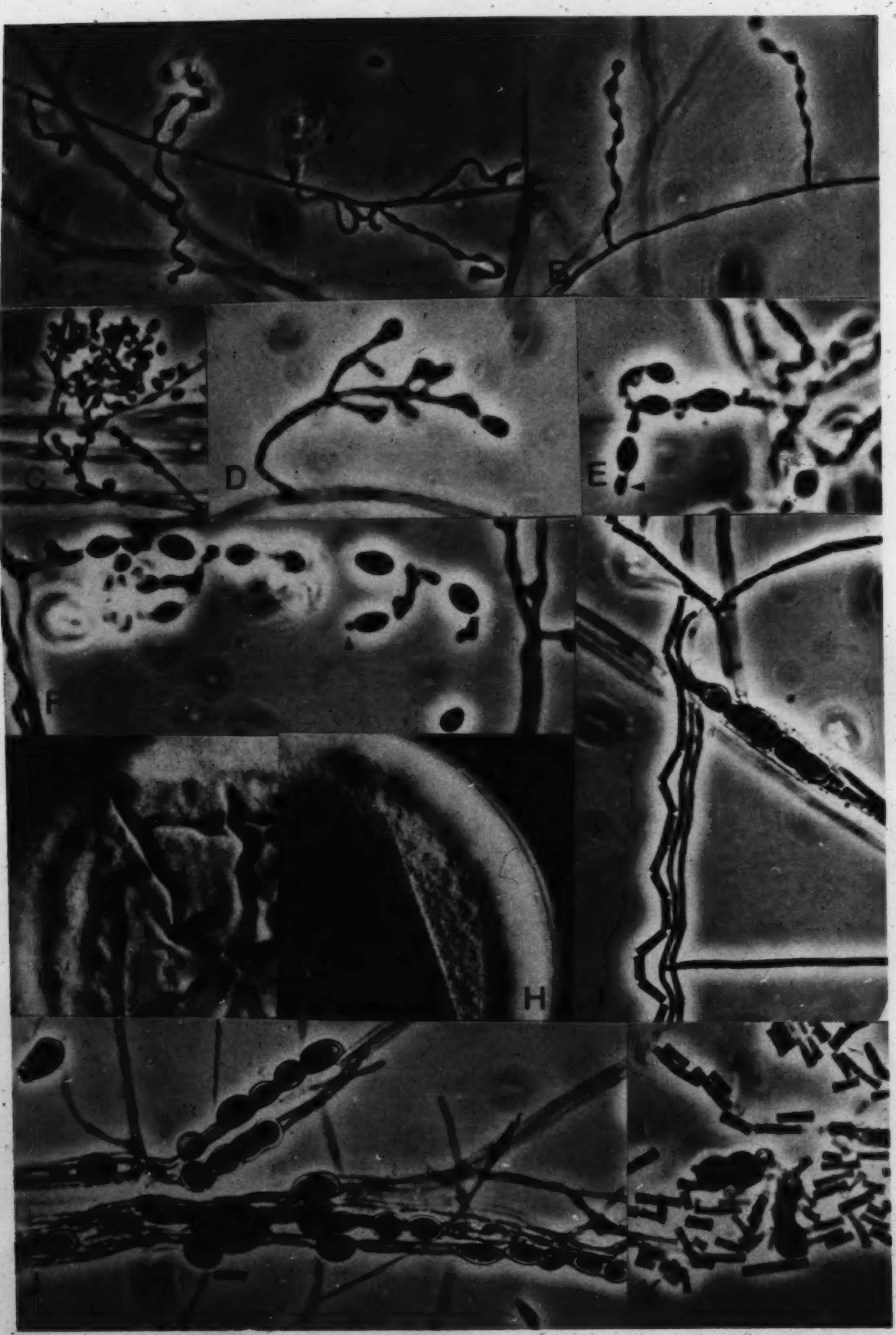
Discussion

O. pannorum differs from O. asperulatum in forming conidia in short chains of 2 to 4, and in forming aleurioconidia laterally on the hypha.

Considerable variation in colonial morphology is apparent in strains of O. pannorum. However, the perfect state, P. roseus, is associated only with isolates having purplish-red colored colonies. Cleistothecia form readily on oatmeal agar at 18 C. It appears likely that O. pannorum is a complex composed of more than one species; however, the uniform microscopic morphology precludes separation into additional species for the present.

One of the strains examined (UAMH 3775, CBS 298.49) was received from the CBS as Onygena piligena, isolated from woollen slipper by R. Heim. The microscopic and colonial morphology of this strain conforms to O. pannorum. The relationship between O. pannorum and Onygena piligena is uncertain, though presumably this strain was isolated from ascocarps found on the natural substrate. However, no ascocarps have been produced by this strain in culture. The ascocarps of Onygena are notoriously difficult to reproduce on artificial media, though Tubaki (1960) induced ascocarp formation in O. corvina by growing it on a medium enriched

Figure 7. A-B. *Ovadendron sulphurea-ochracea* (UAMH 181a). C-D. *Ovadendron pannorum* (3775). E-F. *Ptychogaster albus* (3813). G-J. *Scytalidium lignicola* (1502). K. *Scytalidium album* (3620). Figs. 7A-7B. Arthroconidia in chains on coiled lateral branches. Figs. 7C-7D. Aleurioconidia and arthroconidia borne on verticillately branched conidiophores. Figs. 7E-7F. Chains of conidia developing serially (arrow) and forming clamp connections between each conidium. Figs. 7G-7H. Colonial morphology after 21 days at 25 C. G on PYE, H on cereal. Fig. 7I. Hyaline arthroconidia formed by fragmentation of undifferentiated hypha. Fig. 7J. Chains of thick walled brown arthroconidia. Fig. 7K. Mature arthroconidia of both types. Colonies x 1.0, others x 830, except D, x 2300.


B
C
D
E
F
H
I

with owl's claw or human fingernail. Difficulties are also encountered in inducing initial ascospore germination (Tubaki, 1960).

The cellulolytic activity of this strain (UAMH 3775) suggests that this isolate was probably a contaminant as Onygena is strongly keratinolytic (Tubaki, 1960).

Habitat and Activities

O. pannorum is ubiquitous and has a world wide distribution (Carmichael, 1962; Williams and Pugh, 1974).

This species is cellulolytic. O. pannorum does not digest keratin, but some strains penetrate the hair by single hyphae.

Material Examined

UAMH 650, plate contaminant, 1959; UAMH 1561, blood transfusion flask, 1962, from de Vries, CBS as 117; UAMH 1643, as Geomyces vinaceus, 1957, from Kuehn, Medford, New Jersey as 1; UAMH 1860, soil, Dugway, from Orr as 10 DM; UAMH 3775, woollen slipper, R. Heim, from CBS as 298.49 (Onygena piligena);

Material of Pseudogymnoascus roseus: UAMH 1644, ? TYPE strain of Pseudogymnoascus vinaceus, by Dal Vesco, Italy, from H. Kuehn, Medford, N.J. as 2; UAMH 1736, same strain as 1644 from Orr as 'P.g. Dal Vesco'; UAMH 1990, soil, Wisconsin, from Orr as QM 6969; UAMH 2005, soil, Japan, from

Orr as NHL 2284; UAMH 2879, soil under Pinus contorta, Kananaskis, Alberta, by P. Widden, 1967, from G. Bhatt, U. Calgary, Alberta, as 70 (=CBS 387.69); UAMH 3001 and 3002, from R.A. Morrall, Univ. Saskatchewan, as RM 2509 (SSF176) and RM 2169 respectively; UAMH 3166, mouse dung, Claremount, California, by R.K. Benjamin, 1965, as 1558; UAMH 3337, TYPE of Gymnoascus rhousiogongylinus, forest soil, Parry Sound, Ontario, by H.M. Wener, 1970, from Cain, U. Toronto Herbarium, as TRTC 45536 (CBS 722.69); UAMH 3875, Orr (O-3729)

Ptychogaster Corda 1838

Type Species

Ptychogaster albus Corda 1838, Icones Fungorum II:23-24, Taf. XII, fig. 90

= Ceriomyces albus (Corda) Saccardo 1888, Sylloge Fungorum 6:388

= Ptychogaster fuliginoides (Pers. ex Steudel) Donk 1972, Proc. K. Ned. Akad. Wet. C 75:165-177

Perfect State:

Tyromyces ptychogaster (Ludwig) Donk 1933, Mededeelingen Botanisch Museum Herbarium Rijks Universiteit 22:153

= Polyporus ptychogaster Ludwig 1880, Zeitschr. ges. Naturwiss. III, 5:424-431

= Oligoporus ustilaginoides Brefeld 1889, Untersuchungen aus dem Gesammtgebiete der Mykologie, Heft 8:114-142, Taf. VII, fig. 23-25 and Taf. VIII, fig. 26-33

According to von Arx (1973), the fungus described by Corda as Ptychogaster albus was transferred by Saccardo (1888) to Ceriomyces. Brefeld (1889), including it in Oligoporus as O. ustilaginoides, provided excellent illustrations.

Illustrations by Brefeld (1889) of two species O. ustilaginoides and O. farinosus are similar and closely resemble an isolate (UAMH 3813, WFPL 170AD) received as Ptychogaster albus, from Picea, Nova Scotia.

Development of conidia in Ptychogaster albus resembles Arcuadendron. Conidia are formed in chains, with the conidiogenous cells occurring serially, developing from the apex of the newly formed conidium (Figs. 7E,7F). Ptychogaster albus differs, however, in forming clamp connections between each developing conidium (Fig. 7E). Mature conidia are yellow, smooth, ellipsoidal, ovoidal or barrel shaped, 4-5um x 6-9um, released by lysis of the intervening hypha.

Conidia of Ptychogaster rubescens Boudier develop in the same manner. For a description of P. rubescens, refer to Fidalgo (1958) and von Arx (1973).

P. albus and other species of Ptychogaster are conidial states of polypores. In nature, the imperfect Ptychogaster stage grows as cushion shaped sporophores resembling conks, or small pads, composed of hyphae and powdery masses of conidia, or grows within the basidiocarp (Corda, 1838; Brefeld, 1889; Rea, 1922 p. 660; Donk, 1933; Davidson, Campbell and Weber, 1942; Davidson, Christensen and Darley, 1945; Fidalgo, 1958; Singh, Singh and Bakshi, 1961).

Habitat

On wood of various types including Pinus, Abies, Picea, and mine timber wood, South Africa, Germany, Canada, India and the USA.

Scytalidium Pesante 1957

Generic Description

The form-genus Scytalidium is characterized by dematiaceous intercalary or terminal arthroconidia formed by fragmentation of undifferentiated hyphae. The arthroconidia are thick-walled, smooth, occasionally verrucose in age, 0-1 septate, pale to mid-brown, or yellowish brown, cylindrical, oblong or broadly ellipsoidal, and if septate, often constricted at the septum. Fission arthroconidia of a second type are hyaline, thin walled, smooth, cylindrical, single celled. (Also refer to Ellis, 1971.)

In its thallic ontogeny, Scytalidium most closely resembles Geotrichum but is distinguished by its dematiaceous appearance.

KEY TO THE SPECIES OF Scytalidium .... Table II

Type Species

Scytalidium lignicola Pesante 1957, Annali de la
sperimentazione Agraria (Roma) II, suppl. CCLXI-CCLXV;
Ellis 1971, Dematiaceous Hyphomycetes p. 28, fig. 2

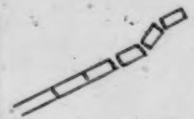
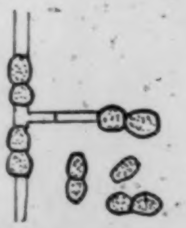
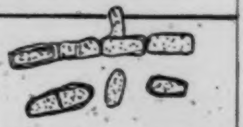
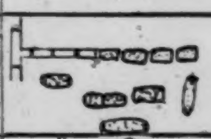
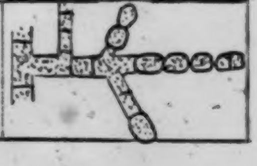
Description

Growth on PYE (Fig. 7G) is rapid reaching a diameter of 70 mm or filling the petri dish by 14 days. At first white, the colony turns dark tan, pale grey or dark grey in color, front and reverse, and is flat with raised radial folds, downy or wooly, dense, matted. Brown or black pigment is excreted into the agar. In addition the type culture (UAMH 1506) forms large dark brown exudate droplets on the surface.

On cereal agar (Fig. 7H), growth is slightly more rapid (80-90 mm in 14 days) but the aerial growth is scant. Colonies at first are flat, glabrous with reddish tan surface growth, gradually turning black as sporulation commences and with a loose weft of white cottony aerial growth. The agar turns plum or grey in color from diffused pigment. UAMH 2816 differs in growing faster than the type

TABLE II

KEY TO THE SPECIES OF SCYTALIDIUM

Species	Growth Rate	Colony Color	Pigment	Activity	Growth 37 C	Arthroconidia			
						Size	Septa	Color	Figure
Scytalidium lignicola	Rapid	Tan Grey Black	Brown Plum	C	-	2 x 4.5-8 um 4-7 x 7.5-17um	0 0-1	Hyaline Yellow-Brown	
Scytalidium album	Rapid	White Grey	Yellow Grey	C	-	2 x 5-8um 4.5-6(9) x 6.5-14-16um	0 0-1	Hyaline Yellow-Brown	
Scytalidium aurantiacum	Rapid	Yellow	Yellow Orange	C	-	2 x 3.5-6um 4.5 x 8-13.5um	0 0-1	Hyaline Yellow-Brown	
Scytalidium acidophilum	Slow	Grey-Brown	-	C	Scant	4.5-6.5(8) x 7-23um	0-1	Brown	
Scytalidium flavobrunneum	Rapid	Peach Grey	Yellow	C	-	3.5-5 x 5.5-12(22) um	0-1	Brown Refractile Apices	
Scytalidium state of Hendersonula toruloidea	Rapid	Grey Black	Grey	C K?	?	3.5-5 x 6.5-15um	0-1	Brown	

C Cellulolytic
K Keratinolytic
- Absent

culture (UAMH 1506) and in forming dense black colonies resembling a coating of thick tar on the cellophane membrane.

There is no growth at 37 C.

Hyphae septate, hyaline, becoming brown. Arthroconidia of one type, formed by fragmentation of hyaline hyphae (Fig. 7I) are cylindrical, thin-walled 2um x 4.5-8um. Arthroconidia of the second type (Fig. 7J) arising in chains in an intercalary or terminal position on short, lateral branches, become thick walled, yellowish brown, broadly ellipsoidal, or oblong or barrel shaped, 0-1 septate, constricted at the septum, and show an increase in volume. Arthroconidia measure 4-7um in width and 7.5-12um in length if 0-septate and 12-17um if 1-septate. Arthroconidia are not readily detached and may appear surrounded by a brown slime.

Habitat and Activities

Isolated from blue stain of wood of Platanus, Pinus, Picea, Abies, Betula, Populus and Arachis, and from soil and roots of Vitis, in Italy, Sweden, southern USA, Canada, Japan, Cyprus, England, India, Rhodesia (Shields, 1969; Ellis, 1971; Murao, Oda and Matsushita, 1973; Klingström and Johanssen, 1973) and also from rhizosphere of Trifolium alexandrinum, Pakistan (Hussain and Malik, 1972).

S. lignicola digests cellophane slowly, but fails to penetrate hair.

Klingstrom and Johanssen (1973) testing the antagonistic properties of several isolates of S. lignicola against Fomes annosus, Polyporus versicolor, Lentinus lepideus, and Coniophora puteana found S. lignicola overgrew all isolates, in the process killing the decay fungi.

Material Examined

UAMH 385, photomicrographs of DAOM 59090, from presumed type; UAMH 1502, TYPE, from Platanus wood, Italy, by Pesante and Peyronel, 1956, received from CMI as 62532 (CBS 233.57); UAMH 2816, from cornfield soil, Bright, Ontario, by G.C. Bhatt, 1967, as U.W. 655.

Two other species, Scytalidium album Beyer and Klingstrom and S. aurantiacum Klingstrom and Beyer having morphological and physiological differences from S. lignicola have been described. Microscopically, it is difficult to differentiate among the three species, the size of the arthroconidia of both S. album (Fig. 7K) and S. aurantiacum falling within the range for S. lignicola.

Scytalidium album Beyer and Klingstrom 1965, Svensk
Botanisk Tidskrift 59(1):35

Colonies grow rapidly (50 mm on PYE and 70 mm on cereal at 14 days) and are white, flat, downy or glabrous. As sporulation begins, the surface growth on cereal turns grey, and a grey pigment diffuses into the medium, with an orange pigment forming near the center. On DSA the pigment turns the agar bright lemon yellow.

Klingstrom and Beyer (1965) and Klingstrom and Johanssen (1973) distinguish *S. album* from *S. lignicola* by its moderate growth at 25 C, and its inability to grow at 35 C, by its whitish colored colonies and pale yellow pigmentation on malt agar, and its antagonistic properties.

Habitat and Activities

Occurrence: Isolated from blue stain of wood of *Betula*, *Acer*, *Populus*, *Pinus*, *Abies*, *Picea*, and *Pseudotsuga* (Douglas fir) utility poles, in Sweden, Finland, eastern Canada and western USA (Klingstrom and Beyer, 1965; Ricard and Bollen, 1968; Klingstrom and Johanssen, 1973).

Antibiotic Activity and Metabolites: Klingstrom and Johanssen (1973) studying the action of *S. album* against four decay fungi found inhibition resulted from a soluble substance excreted into the medium. Production of a yellow pigment was associated with antagonistic ability, but the pigment itself had no antibiotic activity. The active agent was extracted from culture filtrates of *S. album* and found to be inhibitory to *Fomes annosus*.

One of the *S. album* strains studied by Klingstrom and

Johanssen (1973) was the FY strain (UAMH 3620) of Ricard and Bollen (1968). Considerable interest has been generated in the metabolites produced by this strain. Ricard and Bollen (1968) reported inhibition of the wood decay fungus Poria carbonica and some bacteria by culture filtrates. Stillwell, Wall and Strunz (1973) isolated and defined the structure of scytalidin, a second antiobiotic compound active against a wide variety of fungi. In addition to scytalidin, other antibiotic agents were present in culture filtrates, active against some fungi where scytalidin was not.

Findlay and Kwan (1973 a,b) defined another major metabolite, scytalone (3,6,8 -trihydroxytetralone) and a minor one (6,4,8 -dihydroxytetralone), neither of which were inhibitory to any significant degree. Similarly, Geigert, Stermitz and Schroeder (1973) isolated two other compounds, hexenophenones, neither inhibitory to Poria carbonica.

Activity: S. album is cellulolytic, digesting cellophane after prolonged growth. It does not attack hair.

Material Examined

UAMH 3611, TYPE, from Norway spruce at Garpenberg, Sweden by Klingstrom and Beyer, 1963 (FF28), received from CBS as 372.65; UAMH 3620, from heartwood of Douglas fir utility poles, western Oregon, by Ricard and Bollen (FY), received from Wang, N.Y. State University, Syracuse as 1041.

Scytalidium aurantiacum Klingstrom and Beyer 1965, Svensk Bot. Tidskr. 59(1):35

Colonies grow moderately rapidly (40 mm on PYE and 65 mm on cereal at 14 days). On PYE colonies are pale yellow, flat with a woolly matted texture appearing coarse or bristly. A lemon yellow pigment diffuses into the agar on PYE and DSA.

Klingstrom and Beyer (1965) and Klingstrom and Johanssen (1973) distinguish *S. aurantiacum* from *S. lignicola* by its slower growth at 25 C and its inability to grow at 35 C. *S. aurantiacum* differs from *S. album* in the yellow-red color of the colonies and visible spots apparent on malt agar. *S. aurantiacum* was found to be antagonistic to some human pathogenic bacteria and to a number of wood decay fungi. Three isolates studied by Klingstrom and Johanssen (1973) were lethal for the decay fungi *Fomes annosus*, *Polyporus versicolor*, *Lentinus lepideus* and *Coniophora puteana*.

Habitat and Activities

Isolated from pulpwood of *Pinus*, *Betula* and *Picea* in Sweden (Klingstrom and Johanssen, 1973).

S. aurantiacum is cellulolytic weakening the cellophane membrane after prolonged growth.

The single isolate examined penetrated hairs by single hyphae with no visible digestion of the hair.

Material Examined

UAMH 3612, TYPE, from pulpwood of Pinus silvestris at Skinnskatteberg, Sweden, by Klingstrom and Beyer (FF21), 1962, received from CBS as 374.65.

Scytalidium acidophilum Sigler et Carmichael 1974,

Can. J. Microbiol. 20(2):267-268

Arthroconidia formed in extended chains (Fig. 8A), not easily detached, are brown, thick walled, smooth or verrucose in age, 0-1 septate, measuring 4.5-6.5(8) x 7-13(16)um if single celled and 4.5-6.5(8) x (10)11.5-23um if two celled. In shape, mature arthroconidia are broadly ellipsoidal, cylindrical or irregulary shaped, and if septate, constricted at the septum.

Sporulation and growth is enhanced on acid medium. Colonies grow slowly (21-26 mm in 21 days on cereal agar) and are dark grey brown, reverse dark grey, furrowed, cracked with a thin velvety nap. There is scant growth at 37 C.

Habitat and Activities

Isolated from acid soil near sulfur stockpiles, uranium mine drainage water, and acid solutions containing 4% copper sulfate from an industrial plant, Canada and U.S.A. (Sigler and Carmichael, 1974; Starkey and Waksman, 1943).

S. *acidophilum* is tolerant to extreme acidity and high concentrations of copper (Starkey and Waksman, 1943; Starkey, 1973; Gould, Fujikawa and Cook, 1974). Sensitivity to copper increases as the pH approaches neutrality (Starkey, 1973).

S. *acidophilum* neither attacks cellophane nor digests hair.

Material Examined

From soil near sulfur pile, Bowden, Alberta: UAMH 3460 (CMI 183518, DAOM 145649, CBS 270.74, ATCC 26772) TYPE, November 1971; UAMH 3492, 3493, 3494 (CMI 183519, CBS 271.74, ATCC 26773), June 1972; From liquid: UAMH 3489 (CMI 173066, CBS 421.73, ATCC 24569) from industrial plant acid solutions, 'Fungus D' of Starkey and Waksman (1943); UAMH 3535 (CMI 183521, CBS 272.74, ATCC 26774) from uranium mine drainage water, Ivarson, 1972.

Scytalidium *flavo-brunneum* (Miller, Giddens et Foster)
Sigler comb. nov.
= *Geotrichum* *flavo-brunneum* Miller, Giddens, et Foster
1957, Mycologia 49:792, figs. 5-7 (Basionym)

This species forms brown arthroconidia in chains on lateral branches (Figs. 8B,8C); conidiophores are absent. Fertile branches formed on hyaline vegetative hyphae, become regularly septate with a concentration of cytoplasm. At disjunction the conidia (Fig. 8D) are cylindrical, truncate or oblong, expanded in volume, brown with refractile hyaline apices (Figs. 8D,8E) predominately single celled and measure 3.5-5um x 5.5-12(22)um.

Multiseptate conidia (Fig. 8F) occasionally forming in old cultures are brown with refractile septae, smooth walled, curved with a narrow base and truncate or pointed apex, 5-6um x 10-25um. Short hyaline filaments often remain attached at either end.

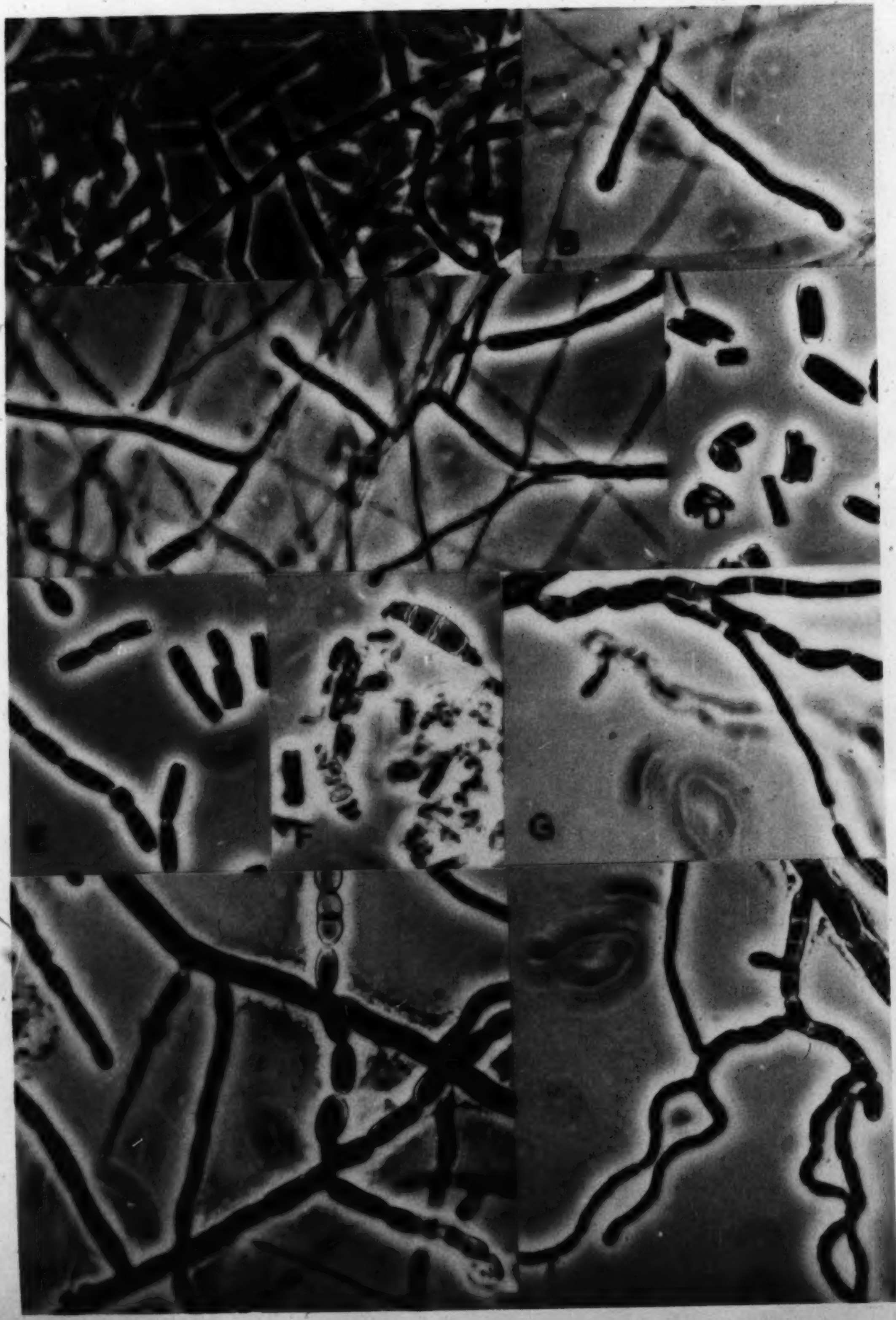
Colonies on PYE growing rapidly (70 mm in 14 days) are effuse, velvety, peach or salmon colored, becoming brown, reverse dark yellow, adhering poorly to the cellophane membrane and developing radial folds or detaching from the membrane at the periphery. No growth occurs at 37 C.

On cereal agar colonies just filling the petri dish by 14 days, are flat with small central umbo and few outward radiating folds, effuse, velvety, with dark grey aerial hyphae and yellow surface growth. Yellow exudate droplets form on the surface and the medium turns yellow or orange from diffusing pigment. On DSA the pigment is bright yellow.

There is no growth at 37 C.

Figure 8. A. *Scytalidium acidophilum* (UAMH 3460). B-F. *Scytalidium flavo-brunneum* (B,C-3487; D,F-617). G-I. *Scytalidium* state of *Hendersonula toruloidea* (3770). Fig. 8A. Chains of thick walled arthroconidia. Figs. 8B-8C. Fission arthroconidia forming on lateral branches. Figs. 8D-8E. Mature brown arthroconidia with hyaline apices. Fig. 8F. Multiseptate conidia. Figs. 8G-8I. Chains of arthroconidia forming on broad hyphae or narrower lateral branches. All x 830.

17


B
F
G

Habitat and Activities

Occurrence: Reported from soil, Georgia and Wyoming (Miller *et*. *al*., 1957; Boeck, Hoehn, Westhead, Wolter, and Thomas, 1975).

Antibiotic Activity: Boeck *et*. *al*. (1975) reported antifungal activity of culture filtrates from an organism which they called *Geotrichum flavo-brunneum*. In assessing the antibiotic activity of the fungus, the authors observed that no other *Geotrichum* was known to produce antifungal agents. Because of its dematiaceous nature, *G*. *flavo-brunneum* has been transferred to *Scytalidium*, a genus having several other species which also produce antibiotics.

The antibiotic agent, isolated and characterized as an azasteroid (Michel, Hamill, Larsen and Williams, 1975) was found to have one major and six minor components. The major component was active against several pathogenic fungi, including *Candida albicans* and *Trichophyton mentagrophytes*, but minimally inhibitory to bacteria (Gordee and Butler, 1975).

Activity: *S*. *flavo-brunneum* digests cellophane after prolonged growth. Keratin is not attacked.

Material Examined

UAMH 617, received from Pfizer and Co., 1958, determined by B. Sloan; UAMH 3487, TYPE, from forest soil, Clarke Co., Georgia, by J.H. Miller, 1956, received from CMI as 100715.

Scytalidium state of *Hendersonula toruloidea* Nattrass 1933,
Trans. Brit. mycol. Soc. 18:197

History

The arthroconidial state of *Hendersonula toruloidea* is frequently recovered from moribund tissues of fruit and trees in warm climates. Nattrass (1933) isolated the conidial state from die-back disease of stone fruit trees in Egypt and reported development of pycnidia only after prolonged growth on wood. He described the arthroconidial state as characteristic of *Torula*.

Wilson (1947) comparing a fungus isolated from branch wilt disease of Persian walnut with two others from damaged citrus trees in California, noted the similarity of his isolate to *H. toruloidea* but failed to find pycnidia. He described a new species, *Exosporina fawcetti*. Later Wilson (1949) induced pycnidial formation in wood experimentally inoculated with *E. fawcetti*, and concluded that *E. fawcetti* was the conidial state of *H. toruloidea*.

Oudemans (1904) created the genus *Exosporina* for a single species *E. laricis* which he found growing on twigs and needles of the larch (*Larix decidua*). Oudemans (1904) described conidia developing in chains from a stroma. Immature conidia at the base of the chain were cubical, whereas mature conidia at the apex became more rounded. The description and illustrations of Oudemans (1904) suggest that Exosporina is an earlier name for Ojibwaya (Sutton, 1973) reported on stems of juniper.

The meristem arthroconidia of E. laricis differ from the fission arthroconidia of H. toruloidea. The Scytalidium state has been previously described but not named by Hughes (1952, 1953); therefore, a new combination is proposed in Scytalidium:

Scytalidium fawcetti (Wilson) Sigler comb. nov.

= Exosporina fawcetti Wilson 1947, Hilgardia 17(12):427, fig. 2 (Basionym)

Description

The Scytalidium state is characterized by dark grey-black effuse rapidly growing colonies often forming upright narrow threads of hyphae. Chains of arthroconidia develop on undifferentiated broad (4-7um) brown hyphae (Fig. 8H), often surrounded by a brown slime, or narrower (3-4um) lateral branches (Figs. 8G,8I). Arthroconidia (Fig. 8H) are 0-1 septate, smooth walled, brown, at first cylindrical truncate, rapidly rounding up and becoming barrel shaped or subglobose, 3.5-5um x 6.5-15um (2.5-7um x 2.5-10(15)um of Campbell, 1974). For a more detailed description, refer to Campbell (1974).

Habitat and Activities

Occurrence: Reported from fruit trees of many types principally citrus and stone fruit (Nattrass, 1933; Wilson, 1947, 1949; Hughes, 1952; Calavan and Wallace, 1954) and Persian walnut, black walnut, European chestnut (Wilson, 1949; Calavan and Wallace, 1954). All are tropical varieties.

Pathogenicity: Recently, _H_. _toruloidea_ has been recovered from infections of the skin and nails in humans (Gentles and Evans, 1970; Campbell, Kurwa, Abdel-Aziz and Hodgson, 1973; Campbell, 1974). Most infections were reported in former natives of tropical countries now residing in Great Britain.

Pycnidia: Nattrass (1933) and Wilson (1949) induced pycnidial production in _H_. _toruloidea_ by growing the organism for long periods in wood.

Pycnidia have rarely been observed in isolates from human infections (Gentles and Evans, 1970; Campbell, 1974) although Campbell _et_. _al_. (1973) reported 5 of 8 isolates eventually developed pycnidia. Campbell (1974) induced pycnidial formation in 2 of 25 isolates by exposure to ultra-violet irradiation.

The single strain examined here (UAMH 3770) first formed pycnidia after exposure to ultra-violet light. During the process of drying, colonies (see Materials and Methods) are exposed overnight to a General Electric germicidal 15 w lamp, and when dried are placed in plastic bags for storage. However, the agar was not sufficiently dried and the incompletely dried colony eventually formed pycnidia within the plastic bags. Subsequently, pycnidia developed on straw agar (chopped decomposing straw, 3%; agar 1.5%) after 49 days incubation at 25 C.

The pycnidial state has been described by Nattrass (1933), Wilson (1949) and Hughes (1952).

Activity: H. toruloidea digests cellophane. Campbell (1974) reported penetration of keratin of hair by single hyphae, and penetration of the nail.

Material Examined

UAMH 3770, from fingernail of Jamaican-born resident of England, at Univ. of Birmingham, by C.K. Campbell (M40)

Sporendonema Desmazieres 1827

History

In 1827 Desmazieres described and illustrated Sporendonema casei which he found growing on outer crusts of cheese. In his original analysis, Desmazieres noted the affinity of S. casei to Mucor crustaceus Bulliard, Aegerita crustacea De Candolle, and Oidium rubens Link and suggested that none of these authors had correctly interpreted the manner of spore formation.

Desmazieres recognized two different forms of spore dissemination, one through release from the tip of the fertile hypha and the other by destruction of the outer hyphal wall. Disagreement among mycologists on the exact nature of spore formation and dehiscence has resulted in considerable confusion over the placement of this species.

S. casei was transferred to *Torula* Persoon as *T. casei* by Corda (1838) and later as *T. sporendonema* by Berkeley and Broome (1850). Berkeley and Broome disagreed with Desmazieres' interpretation of spore formation and noted "Corda's *Torula Casei* appears to be very different".

Bonorden (1851) followed Fries (1832) in accepting Desmazieres' *Sporendonema casei* as the correct name for this fungus, and later Bainier (1907) reviewed *S. casei* and described two new species.

However, Saccardo in 1882 referred *Torula sporendonema* Berk. and Broome to *Oospora* Wallroth, a nomen illegitimum, as *O. crustacea* (Bulliard) [=*Mucor crustaceus* Bulliard]. In 1886 Saccardo placed *Sporendonema casei* in synonymy with *O. crustacea*. Lindau (1907) accepted this transfer.

Sumstine (1913) further complicated the taxonomy of this fungus by stating that *O. crustacea* [=*S. casei*] was conspecific with *Oospora lactis* (Fres.) Saccardo = *Geotrichum candidum* Link. Sumstine also considered *Chalara mycoderma* Bonorden, another species referred to *G. candidum*, as a possible synonym of *S. casei*.

Oudemans in 1886 according to Lindau (1907) emended *Sporendonema* to include a new species *S. terrestre*. Although Lindau (1907) accepted this species, the status is uncertain. Arnaud (1952) in describing *Nyctalina lignicola* noted its resemblance to *S. terrestre*.

In classifying a fungus isolated from curing blue cheese, Hammer and Gilman (1944) outlined the dilemma in naming the fungus. They reviewed the literature and recommended retention of the name *Sporendonema casei* based on Desmazieres' original interpretation. In addition, the authors accurately and precisely recorded the conidium development of *S. casei*.

More recently, von Arx (1970) also accepted *Sporendonema casei* Desmazieres.

Generic Description

Hyphae septate, broad, hyaline; conidiophores lacking. The fertile hyphae are branched, often dichotomously, at first sparingly then more regularly septate, with septae forming first near the apex of the hypha. Arthroconidia are formed by condensation of the cytoplasm in adjacent or more often alternate segments separated by one or more empty cells. Maturing arthroconidia, retained within the original outer hyphal wall, become thick walled and are released by fracture or lysis of the intervening empty cell. Arthroconidia are hyaline or pink or yellow, broad, mostly greater than 4um in diameter, smooth, thick walled.

Sporendonema is distinguished from *Coremiella* by its light colored hyphae and arthroconidia. Furthermore *Coremiella* may develop coremia especially on natural substrates, though rarely in culture. Coremium formation has not been reported in *Sporendonema*.

Malbranchea differs from *Sporendonema* in the width of the hyphae and arthroconidia which in *Malbranchea* rarely exceeds 4um.

Type Species

Sporendonema casei Desmazieres 1827, Ann. Sci. Nat. XI:247; Desmazieres 1827, Rec. Trav. Soc. Sci. Agric. Arts, Lille p. 185-187, pl. 3

= *Torula casei* (Desm.) Corda 1838, Icones Fungorum 4:8, fig. 36

?= *Mucor crustaceus* Bulliard 1782, Bull. Champ. Tab. 100

= *Oospora crustacea* (Bull.) Saccardo 1882, Michelia 2:545

?= *Aegerita crustacea* DeCandolle 1805, Fl. France 2:72

= *Torula sporendonema* Berkeley et Broome 1850, Ann. Mag. Nat. Hist. ser. 2, 5:460

?= *Oidium rubens* Link 1815, in Mag. Ges. Naturf. Freunde, Berlin 7:37

If Desmazieres' assertion that Aegerita crustacea DeCandolle is the same species as S. casei can be validated then this earlier specific epithet would take precedence. Similarly Link's brief description of Oidium rubens is difficult to interpret with certainty but it too may be an earlier specific epithet for S. casei.

Description

S. casei is psychrophilic, growing and sporulating well at 8 C. Colonies grow slowly at 25 C with scant sporulation and fail to grow at 30 C. At 18 C, colonies on PYE agar reach a diameter of 30 mm and are flat, downy, creamy white front and reverse, whereas on cereal agar growth is more luxuriant, though slower, and the colony at first creamy white turns cinnamon yellow in color as sporulation commences. The reverse is pink and a pink pigment diffuses into the medium.

In microscopic preparations numerous large dark brown rod shaped crystals may be found.

Characteristically the fertile hyphae, arising as lateral branches from the vegetative mycelium, are slightly broader, mostly curved or loosely coiled, or straight (Figs. 9A,9B) and the cytoplasm is more dense. Septa, forming in more or less regular segments, are thick suggesting double septae (Fig. 9C). Concentration of cytoplasm occurs in alternate or adjacent segments (Fig. 9B) and the internally developing arthroconidia synthesize new wall material. Maturing arthroconidia often become rounded at the corners and the original outer hyphal wall remains visible. Mature arthroconidia (Fig. 9D), released by fracture, sometimes remaining connected in groups of 2's or 3's , are yellow or hyaline, oblong, smooth (3) 4-5um x 4-8 (10) um. In old cultures, cinnamon colored arthroconidia are released not only by fracture of the hypha, but also by extrusion from the apex of the outer hyphal tube (Figs. 9E,9F) leaving a section of empty hypha, exactly as described by Desmazieres (1827).

Habitat and Activities

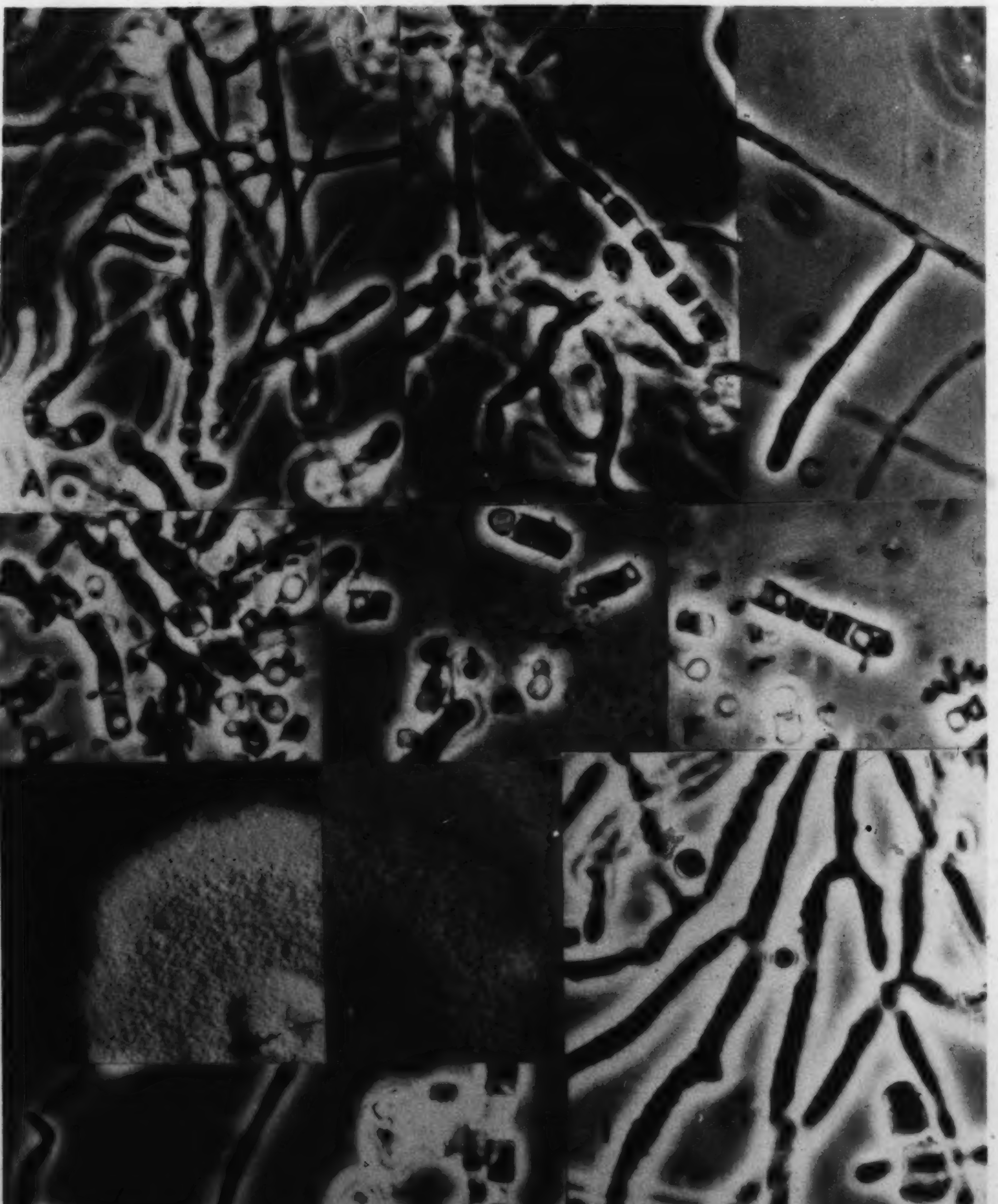
Reported mostly from cheese; other records should probably be referred to Scopulariopsis according to Wakefield and Bisby (1941).

S. casei attacks neither cellophane nor keratin.

Material Examined

UAMH 1506, from cheese, England by Galloway, 1949, received from CMI as 37084; UAMH 1508, from wooden cheese drum, London, England by Worthington, 1957, received from CMI as 68748; UAMH 3790, isolated at Hokkaido University, Japan by Sasaki (AHU 9107), 1963, from Tubaki, IFO, Japan as 7656.

Figure 9. A-F. Sporendonema casei (A,B,D-F-UAMH 3790; C-1506). G-K. Sporendonema purpurascens (G-I,K-432; J-3791). Figs. 9A-9C. Alternate arthroconidia developing on straight or curved fertile hyphae. Fig. 9D. Mature arthroconidia. Figs. 9E-9F. Extrusion of arthroconidia from the apex of the outer hyphal wall. Figs. 9G-9H. Colonial morphology after 21 days at 25 C. G on PYE, H on cereal. Fig. 9I. Dichotomously branched fertile hyphae. Fig. 9J-9K. Alternate arthroconidia. Colonies x 1.0, others x 830.


A

Other Species

Sporendonema purpurascens (Bonorden) Mason et Hughes 1953 apud Wood 1957, Nature 179:328

≡ *Coprotrichum purpurascens* Bonorden 1851, Handbuch allgemeinen Mycologie p. 76, fig. 32 (Basionym)

≡ *Geotrichum purpurascens* (Bonorden) Saccardo 1886, Syll. Fung. 4:40

?= *Geotrichum roseum* Grove 1886, Syll. Fung. 4:40 fide Caretta 1959

≡ *Allonema roseum* Sydow 1934, Ann. Mycol. 32:283

?= *Sporendonema roseum* Grove var. *album* Arnaud 1952, Bull. Soc. Mycol. France 68:192, fig. 3,C,D

History

In 1851, Bonorden described *Coprotrichum* with two species, *C. purpurascens* and *C. cinereum*, illustrating both. Bonorden stated that the hyphae and spores of *C. purpurascens* were purple colored whereas those of *C. cinereum* were greyish colored.

In 1886, Saccardo made new combinations for each species in *Geotrichum*. Later, Windisch (1951) listed *C. cinereum* and *C. purpurascens* as synonyms of *Endomyces lactis* and subsequently Carmichael (1957) in emending *Geotrichum* included all three as synonyms of *G. candidum* Link.

At about the same time, Wood (1957) in a brief report on a disease of cultivated mushrooms caused by a so-called 'red Geotrichum' or 'lipstick mold' cited Mason and Hughes' identification of the causal agent as Sporendonema purpurascens (Bonorden) [= Coprotrichum purpurascens]. According to Wood, the fungus Bonorden described as Coprotrichum purpurascens was not identifiable with G. candidum and should be removed from Geotrichum. Certainly Bonorden's description of the hyphae and spores as purple colored would indicate a difference from G. candidum.

Although Sporendonema purpurascens is the name commonly applied to the fungus known as the 'lipstick mold' (Cole and Kendrick, 1969; von Arx, 1970; Kendrick, 1971, p. 164), Kendrick and Carmichael (1973) in a review of Hyphomycete genera list Coprotrichum purpurascens Bonorden as synonymous with G. candidum.

Caretta (1959) following Redaelli and Ciferri (1934) and Ciferri (1958) in accepting Oudemans' (1886, in Lindau 1907) emended description of Sporendonema Desmazieres, retained Coprotrichum purpurascens for the neotype culture of Wood (1957). However, Redaelli and Ciferri (1934) included in Sporendonema unrelated fungi (Dodge, 1935) and the fungus they called Sporendonema epizoum has been transferred to Wallemia as W. sebi (Fries) von Arx (1970) (see excluded species).

Caretta (1959) listed a number of synonyms for C. purpurascens including Monilia miniata Wallr. (?= S. casei, see Saccardo, 1886, p. 20), Oospora crustacea Sacc. [?= S.

casei Desm.], *Endoconidium luteolum* Delacr., *Oidium rubrum* Proks., *Scopulariopsis casei* Loubiere, ? *Oidium aurantiacum* Henneberg, *Coprotrichum crustaceum* Cif. et Red. and *Coprotrichum lutescens* Cif. et Red. I have not seen the original descriptions of these species.

Description

Colonies on PYE (Fig. 9G) grow moderately rapidly (55-68 mm in 21 days) at first scant cottony white growth, then turning rose pink with a creamy white margin, dense, cottony or more often powdery, flat with a central plateau, dry, with fine surface cracks. The reverse is burnt orange in culture but burgundy colored when dried.

Growth on cereal agar (Fig. 9H) is slightly slower (45-60 mm in 21 days), less luxuriant, cottony, turning from white to peach or pale pink in color. The reverse is white and a tan or pinkish pigment diffuses into the medium below the colony.

There is no growth at 37C, but growth on oatmeal agar is faster at 30 C than at 18 C.

Alternate arthroconidia form on undifferentiated hyphae which may branch dichotomously (Fig. 9I). Arthroconidia (Figs. 9J,9K) are cylindrical or oblong, discoid in end view, hyaline at first, later pink, thick walled, smooth 4-7um x 4-12(15)um.

The formation of arthroconidia has been recorded by time-lapse photography (Cole and Kendrick, 1969).

Habitat and Activities

S. purpurascens is most commonly associated with cultivated mushrooms.

This species is weakly cellulolytic requiring several weeks for digestion to occur. Keratin is not attacked.

S. purpurascens, one of several fungi tested by Komatsu (1969) inhibited *Pholiota nameko in vitro* at 25 C but failed at 12 C.

Material Examined

From mushroom beds: UAMH 432 and 433, received from Kneebone, Pennsylvania State University, as isolates A and B respectively; UAMH 1497, NEOTYPE, Chesham, England, by F.C. Wood, 1951, from CMI as 45638; UAMH 3791, same strain as UAMH 1497, received from Tubaki, IFO as 7659 (CMI 45638).

Species of Uncertain Status

Sporendonema salicis Bainier 1907, Bull. Soc. Mycol. France 23:24, pl. VI, fig. 7-9; Saccardo and Trotter 1913, Syll. Fung. 22:1240

Sporendonema artemisiae Bainier 1907, ibid, pl. VI, fig. 10-12; Saccardo and Trotter 1913, Syll. Fung. 22:1240

Bainier reported this species on dead stems of the mugwort, Artemisia, forming well developed yellowish white or grey tufts (coremia?). It could be Coremiella cubispora (Berk. et Curt.) Ellis. Bainier lists the size of the conidia as 1um12 - 1um25 and Saccardo and Trotter interpret these measurements as 1,12 u - 1,25 u. However, according to the illustrations (all at the same magnification), the diameter of the conidia of Sporendonema artemisiae exceeds that of S. salicis which was given by Bainier as 4um2. These measurements of Bainier appear to be in error.

Sporendonema terrestre Oudemans 1886, Versl. en. Med. Konink. Ak. Wetensch. Amsterdam Afd. Natuurk. 3, ser. 2:115, pl. 1

Sporendonema roseum v. album Arnaud 1952, Bull. Soc. Mycol. France 68:192, fig. 3,C,D

?= Sporendonema purpurascens

Excluded Species

Sporendonema sebi Fries 1849 = Wallemia sebi (Fr.) von Arx 1970

Sporendonema epizoum (Corda) Ciferri and Redaelli 1934 = Wallemia sebi

PART II MALBRANCHEA SACCARDO 1882

History

In 1882 Saccardo established the form-genus Malbranchea for a single species M. pulchella Saccardo and Penzig, found growing on damp cardboard in Rouen, France. Though providing no illustrations, Saccardo described the characteristic branched, arcuate, or curved fertile hyphae. However, in reporting the extrusion of conidia from the apex of the fertile hyphal branch, "ex apice ramulorum continuo exsilientibus", he failed to recognize the arthric nature of conidium dehiscence. Subsequently, Saccardo (1886) repeating his original description referred to the affinity of Malbranchea with Oospora Wallroth and Glycophila Mont. He provided no records of the cultural characteristics of the organism.

Since its original description, Malbranchea has been largely ignored by mycologists. Two other species were described in the period 1925-1935. Miehe (1907) described in detail, Thermoideum sulfureum, a thermophilic fungus, but Saccardo (1908) and Saccardo and Trotter (1913) considered it a synonym of M. pulchella. More recently, attention again focused on the thermophilic isolates when Cooney and Emerson (1964) reviewed the history of Malbranchea and provided an excellent description. The history of the mesophilic and thermophilic species are given under *M. pulchella* and *M. sulfurea* respectively.

Generic Description

Hyphae hyaline, septate; conidiophores absent. Primary hyphae straight, branched, mostly the same diameter, or slightly broader than the fertile hyphae, rarely exceeding 4um in diameter. Fertile hyphae, arising as branches from the primary hyphae, characteristically arcuate, in some species straight, branched, narrow 1.5-3um or wider, rarely exceeding 4um in diameter. Hyphae at first sparsely septate, then regularly so, with concentration of cytoplasm in alternate segments, separated by 1 or more empty cells; arthroconidia released by lysis or fracture of outer hyphal walls of intervening empty cells. Alternate arthroconidia smooth walled, cylindrical-truncate, curved or straight, hyaline, in age, yellow, tan, orange, greenish-yellow, in diameter not exceeding the width of the hypha which bears them.

Type Species

Malbranchea pulchella Saccardo et Penzig 1882, Michelia 2:638

Discussion

Although many other fungi form intercalary arthroconidia, Malbranchea species develop exclusively regular alternate arthroconidia. Species of Malbranchea can be divided into two groups, ones having arcuate or curved fertile hyphae and ones having more or less straight fertile hyphae. However, the primary hyphae of all species are straight, mostly slightly broader than the fertile branches, often forming intercalary arthroconidia which may predominate during early development. The size range of arthroconidia varies little among the species of Malbranchea. For this reason, the colonial morphology and color are important characters in distinguishing among the species. For color photographs of colonies, refer to the Appendix, Fig. 21.

KEY TO THE SPECIES OF Malbranchea

Conidiophores absent 1
Conidiophores hyaline .... Try Ovadendron
Conidiophores pigmented .... Try Oidiodendron
1. Fertile hyphae mostly greater than 4um in diameter .... Try Sporendonema
1. Fertile hyphae mostly narrower 2
2. Fertile hyphae arcuate or curved 3
2. Fertile hyphae straight, branched 11
3. Fertile hyphae tightly coiled, accessory conidia lacking 4

3. Fertile hyphae curved, arcuate, accessory conidia present 6

4. Colonies thermophilic; conidia mostly 2.5-4.5um broad .... *M. sulfurea*

4. Colonies not thermophilic; conidia mostly narrower ... 5

5. Colonies dark gold; perfect state *Myxotrichum* .... *M. circinata*

5. Colonies tan, white or pale brown .... *M. pulchella*

6. Colonies orange 7

6. Colonies pale colored 9

7. Homothallic; perfect state *Auxarthron* .... *A. conjugatum*

7. Not homothallic; perfect state absent 8

8. Arthroconidia intergrade with aleurioconidia formed laterally or terminally .... *M. chrysosporoidea*

8. Aleurioconidia absent .... *M. aurantiaca*

9. Colonies restricted, pinkish-buff; perfect state *Myxotrichum* .... *M. flavoroseus*

9. Colonies some other color 10

10. Colonies ivory yellow, spreading, zonate; *Auxarthron* perfect state .... *M. albolutea*

10. Colonies buff or tan, rarely white, restricted or spreading .... *M. arcuata*

11. Branching of fertile hyphae regularly acute, arborescent .... *M. dendritica*

11. Branching of fertile hyphae otherwise 12

12. Arthroconidia mostly narrow, 1.5-3um 13

12. Arthroconidia mostly broader, 2.5-5um 17

13. Fertile hyphae, repeatedly branched, in dense tufts .... M. flocciformis

13. Branching of fertile hyphae more restricted 14

14. Colonies buff, tan or white 15

14. Colonies lemon yellow .... M. flava

15. Colonies white, restricted .... M. gypsea

15. Colonies buff or tan 16

16. Arthroconidia with refractile terminal walls, mostly 2-3um x 3.5-8(11)um .... M. fulva

16. Arthroconidia broader, 2.5-3.5um x 3.5-6um; uncinate appendages mostly present .... U. reesii

17. Arthroconidia broad, 3-5um, closely spaced .... M. state of C. immitis

17. Arthroconidia narrower, 2.5-3.5um, irregularly spaced; uncinate appendages mostly present .... U. reesii

Malbranchea resembles both Coremiella and Sporendonema in its conidium development. Whereas the former also differs in its dematiaceous nature, both are distinguished by the wide diameter of the hyphae and arthroconidia. Moreover, the perfect states of Malbranchea where known, are in the Gymnoascaceae. The perfect states of Coremiella and Sporendonema are largely unknown but Tubaki (1960) reported that Onygena corvina has a Coremiella conidial state.

Rebell and Taplin (1970) and Rippon (1974) noted the affinity of Malbranchea to some dermatophytes which may form arthroconidia in culture. The relationship of the dermatophytes to perfect states in the Ascomycotina, family Gymnoascaceae, is well established (Nannizzia, Arthroderma). Malbranchea is related to the dermatophytes and Chrysosporium by its perfect states within the Gymnoascaceae, by its arthroconidia and its often keratinophilic nature. However, Malbranchea lacks the characteristic aleurioconidia of these genera.

Perfect States

The conidial states of some Gymnoascaceae have been assigned to a number of form-genera including Chrysosporium (Carmichael, 1962; Apinis, 1970; Rebell and Taplin, 1970; Varsavsky and Orr, 1971; von Arx, 1971; Samson, 1972; Orr and Kuehn, 1972; Fennell, 1973), Oidiodendron (Orr and Kuehn, 1964a; Barron and Booth, 1966; Morrall, 1968; Muller and Pacha-Aue, 1968; von Arx, 1971; Fennell, 1973; Tokumasu, 1973), Geotrichum (von Arx, 1971) and Malbranchea (Kuehn, Orr and Ghosh, 1964; Hubalek, 1974a).

A closely related family, the Onygenaceae, is also known to have arthroconidial and aleurioconidial imperfect states (Tubaki, 1960; Malloch and Cain, 1971; Samson and van der Aa, 1973; Fennell, 1973). The lack of a phialoconidial state distinguishes the Gymnoascaceae from the Eurotiaceae (Stolk and Samson, 1972; Fennell, 1973).

Arthroconidial imperfect states have been described for a number of species of Gymnoascaceae, referred to in earlier reports as oidia, or chlamydospores, or arthrospores (Kuehn, 1955b, 1959; Benjamin, 1956; Apinis, 1964). Orr *et al*. (1963b) defined the term arthroaleuriospore or arthroaleurie to differentiate alternate arthroconidia from the true *i.e.* fission arthroconidia of *Geotrichum*. However, Orr *et al*. (1963a,b) considered the arthroaleuries to be variable and therefore of little value in distinguishing among species.

Several *Malbranchea* species described in this report were found to have perfect states in *Myxotrichum*, *Auxarthron* and a new genus of Gymnoascaceae. In most cases the *Malbranchea* state is predominant and would be used for identification. Although beyond the scope of this work to study in detail all the arthroconidial states of the Gymnoascaceae, a few have been included in which the imperfect state may be confused with other species of *Malbranchea*. However, the cleistothecial state would be most often used for identification.

Species of *Auxarthron* have *Malbranchea* conidial states, two of which are described here. It is possible that the *Malbranchea* state may aid in differentiation among species of *Auxarthron* which are identified primarily by the morphology of the peridial hyphae and appendages (Orr *et al*., 1963a; Samson, 1972). The ascospore morphology and size is quite uniform.

Cleistothecial production in the Gymnoascaceae is stimulated by growth on oatmeal-salts agar (Weitzman and Silva-Hutner, 1967; Padhye et al., 1973) and by the use of several incubation temperatures such as 18 C, 25 C and 30 C. Strains failing to form cleistothecia at 25 C may do so readily at 18 C or 30 C, although the lower temperature more often stimulates development. In addition, keratinophilic isolates form cleistothecia when grown on dextrose-salts agar, a minimal nutrient medium, sprinkled with a keratinous substrate such as hair. Cleistothecial production is enhanced in cellulolytic fungi by growth on a cellophane membrane on the surface of the agar (see Materials and Methods) although the membrane tends to limit cleistothecial formation in keratinophilic isolates. Some, especially degenerate strains or ones maintained for long periods in culture, require an additional stimulus, usually prolonged growth, 6-10 weeks or more, or multiple transfers on oatmeal-salts agar.

Ecology and Distribution

Malbranchea is a common soil fungus having a worldwide distribution. Species are mesophilic, thermotolerant or thermophilic and may be keratinolytic or cellulolytic.

Thermophilic isolates of the species *Malbranchea sulfurea* are cellulolytic and are most commonly associated with self-heating decomposing matter, or dung. Since its description by Cooney and Emerson (1964), this species has been frequently reported (see M. sulfurea).

However, other records of Malbranchea are rare. Few reports of Malbranchea have occurred in surveys of keratinophilic fungi (Rebell and Taplin, 1970; Orr and Kuehn, 1972; Hubalek, 1974a; Hubalek and Balat, 1974; Rippon, 1974; Ajello and Padhye, 1974). However, Malbranchea is a little known genus, and isolates could have been listed as unidentified Chrysosporium species or more probably as imperfect states or as unidentified Gymnoascaceae (Emmons, 1954; Rees, 1967a,b; De Vroey, 1970; Hubalek, 1974a; Caretta and Piontelli, 1975). A number of species of Malbranchea have their perfect states in the Gymnoascaceae. Some keratinolytic thermotolerant species are imperfect states of Auxarthron whereas some mesophilic cellulolytic species are imperfect states of Myxotrichum.

With the exception of the Malbranchea state of Coccidioides immitis which is a human pathogen, there is little evidence to suggest that species of Malbranchea are pathogenic. However, arthroconidia of nonpathogenic species may be transient inhabitants of man and animals, which can be recovered from tissues of animals such as rodents and can survive passage through animals (Emmons, 1954; Kuehn et al., 1964; Orr, 1968; Rippon, 1974). Some species of Malbranchea have been reported as fungi resembling C. immitis (Emmons, 1954, 1967; Plunkett, Walker and Huppert, 1963; Huppert, Sun and Bailey, 1967; Orr, 1968; Orr and Kuehn, 1972).

Temperature relationships and activity of isolates are important in differentiating species of Malbranchea. Incubation at 18 C or 30 C often stimulates formation of the perfect state. Since arthroconidium morphology in many species of Malbranchea is rather uniform, the colonial appearance becomes an important character. The morphology and growth rate of colonies at different temperatures provide considerable aid in differentiation among species.

a) Malbranchea species with arcuate fertile hyphae

Malbranchea albolutea Sigler et Carmichael sp. nov.

Perfect state: Auxarthron Orr, Kuehn et Plunkett 1963a

Description

Colonies on PYE (Fig. 10A) growing moderately rapidly (50-57 mm in 21 days) are pale ivory yellow, reverse yellow, powdery, dry and cracked. The colony is slightly raised with central umbo surrounded by two or three powdery zones and outer downy periphery. The periphery develops deep sectors which are flat, with scant aerial growth, identical to the margin. More downy colonies appear smoother with the zonate pattern and sectoring less evident.

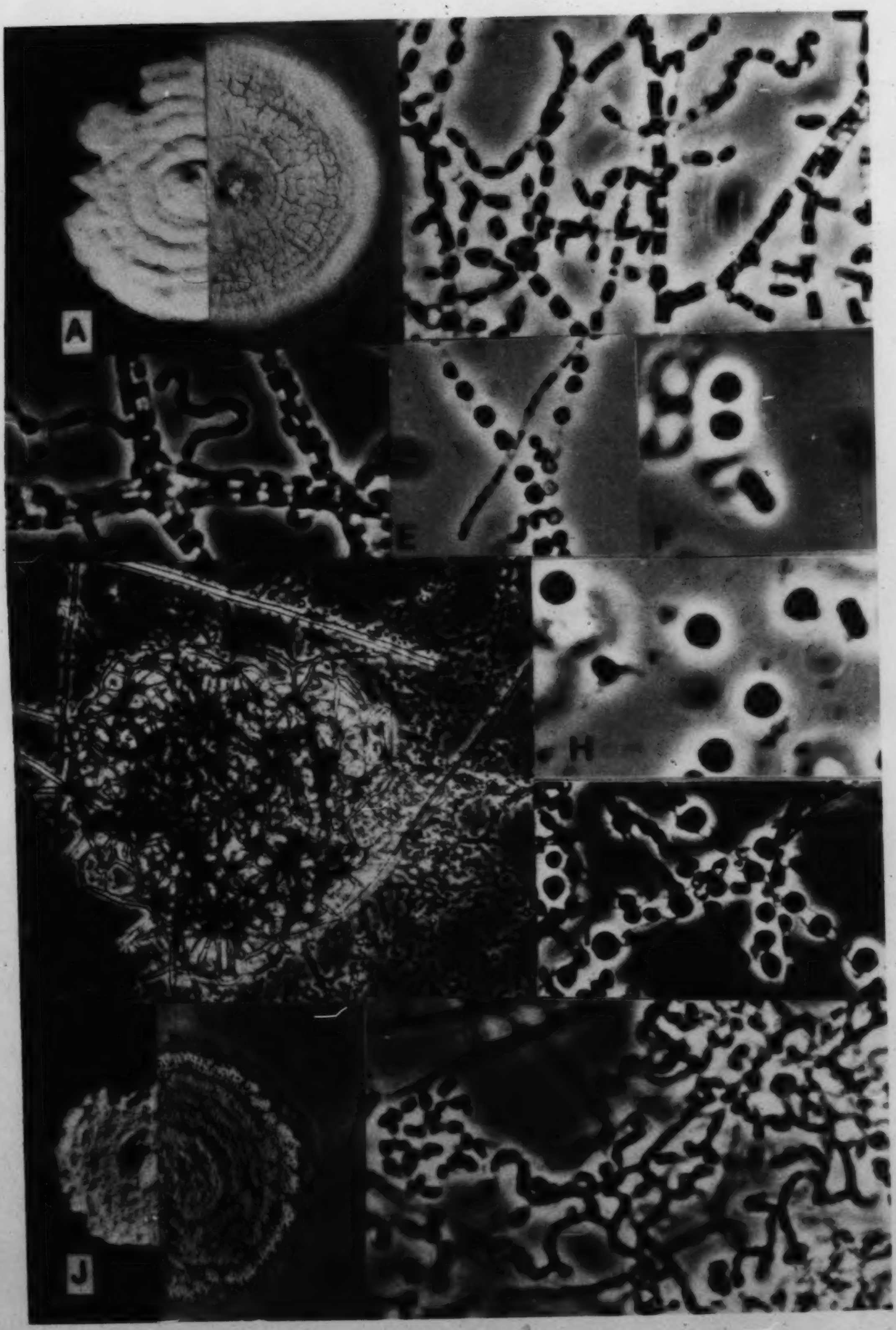
On cereal, colonies (Fig. 10B) grow moderately rapidly (42-53 mm in 21 days) and are pale ivory yellow or creamy buff, reverse yellow, powdery, dry, cracked by numerous tiny fissures, periphery downy, rarely sectoring. The surface is flat, with tiny central umbo or zone of scant aerial growth at center.

Most strains failed to grow at 37 C except UAMH 1846 which showed scant growth. The optimum temperature is 25-30 C.

Arthroconidia borne on narrow, arcuate or curved lateral branches (Figs. 10C,10D) are cylindrical sometimes curved, hyaline, in age yellow, 1.5-2um x (2.5)3-5(6)um. Arthroconidia formed by segmentation of the broader primary hyphae (Fig. 10D) are hyaline, cylindrical 2.5-3(4)um x (1.5)2-5(6.5)um. In age, racket hyphae, and enlarged, subglobose, or irregularly shaped arthroconidia (Fig. 10E) are formed.

Cleistothecia (Fig. 10G) are spherical, discrete, 280-400um in diameter (excluding elongate appendages), brown, composed of a branched network of thick walled, delicately asperulate, septate, 3-5um in diameter, yellow-brown hyphae, with free apices terminating in bluntly pointed spines. Elongate appendages (Fig. 10G) arising from a bifurcate base are 400-800um in length, smooth, thick walled and yellow brown over half the length, tapering to a hyaline apex, straight, rarely uncinate. The hyaline portion is often broken off, leaving the tip blunt. Asci are evanescent, hyaline, 6.5-8um in diameter, 8-spored. Ascospores

Figure 10. A-H. Malbranchea albolutea (A,B,F,G-UAMH 2846; C-1846; D-2861; E-2848; H-3651). I-L. Malbranchea arcuata (I-1861; J-L-2519). Figs. 10A. Colonial morphology after 21 days at 25 C, x 1.0. A on PYE, B on cereal. Figs. 10C-10D. Alternate arthroconidia of arcuate branches and straight primary hyphae, x 830. Fig. 10E. Chains of enlarged arthroconidia, x 830. Fig. 10F. Globose ascospores, x 2300. Fig. 10G. Cleistothecium with elongate appendages, x 210. Fig. 10H. Finely asperulate ascospores, x 2300. Fig. 10I. Chains of enlarged arthroconidia, x 830. Figs. 10J-10K. Colonial morphology after 21 days at 25 C, x 1.0. J on PYE, K on cereal. Fig. 10L. Alternate arthroconidia borne on arcuate branches, x 830.


A
E
F
H
J

(Figs. 10F,10H) are globose, delicately roughened, yellow (2.2)2.5-3.5um.

Holotype: soil, Utah, by G. F. Orr, 1967, UAMH 2846 (O-3508)

Discussion

Malbranchea albolutea differs from other Malbranchea species having arcuate fertile hyphae such as M. aurantiaca and M. arcuata in its creamy white to pale ivory yellow colored colonies. Moreover, the perfect state is produced in culture if isolates are grown on a suitable medium.

Most strains of this species developed cleistothecia only after prolonged growth on oatmeal agar without cellophane. Even when cleistothecia are produced, the colony, on oatmeal agar, remains creamy white in color, never orange or brown. The cleistothecia are slow to mature requiring 6-8 weeks or longer before ascospores are produced. In some strains, even at maturity cleistothecia are formed which appear relatively empty, containing no ascospores. However, ascospores can be induced by repeated transfers on oatmeal agar and growth at 25 C or 30 C. The ascospores appear smooth at low magnification and the rough surface is often difficult to detect even at high magnification (x2700)(Figs. 10F,10H).

The perfect state of M. albolutea is assigned to Auxarthron, a genus distinguished from other genera of the Gymnoascaceae by its net-like anastomosed peridial hyphae bearing prominent enlarged septae, described as 'knuckle-joints' and by its ascospore morphology (Orr *et al*., 1963a). These generic characters described for *Auxarthron* have not been accepted by some others. Apinis (1964) noted that enlarged septae also occurred in some species of *Gymnoascus* and in *Myxotrichum herbariense* [= *Tripedotrichum herbariensis* Orr and Kuehn, 1964b]. Therefore, he retained *Auxarthron* and *Pseudogymnoascus* Raillo as subgenera of *Gymnoascus* based on a broader concept of the genus *Gymnoascus*. Apinis included in the subgenus *Auxarthron* species having uncinate or straight, elongate peridial appendages. Udagawa (1966) followed Apinis in retaining *Gymnoascus*.

Historically, the character of the peridial hyphae and appendages has received emphasis in classification of genera of the Gymnoascaceae. However, Samson (1972) in a study of *Pseudogymnoascus*, *Gymnoascus* and *Auxarthron* pointed to the variability of these characters during different stages and cultural conditions of growth, and suggested that more reliable characters for differentiation were morphology of the ascomatal initials, asci and ascospores. Samson (1972) retained all three genera and distinguished *Auxarthron* from *Gymnoascus* and *Pseudogymnoascus* on the basis of its globose or subglobose, roughened or echinulate ascospores and arthroconidial or aleurioconidial imperfect state.

Eight species have been described in *Auxarthron* (Orr *et* al., 1963a; Orr and Kuehn, 1971, 1972). Samson (1972) suggested that a review of the number of species of Auxarthron should be considered. Species of Auxarthron, which have a rather uniform ascospore size and morphology are difficult to differentiate by the morphology of the peridial hyphae and their appendages.

The perfect state of M. albolutea most closely resembles Auxarthron thaxteri (Kuehn) Orr and Kuehn [= Myxotrichum thaxteri Kuehn, 1955b]. Orr et al. (1963a) described Auxarthron brunneum based on Rostrup's description of Myxotrichum brunneum and placed M. thaxteri Kuehn in synonymy. Apinis (1964) compared Rostrup's type specimen of M. brunneum with the type material of Gymnoascus umbrinus Boudier and found the two identical. Apinis placed M. brunneum in synonymy with G. umbrinus v. umbrinus and retained Kuehn's M. thaxteri as a variety, G. umbrinus var thaxteri. Based on their evaluation of the type materials of Rostrup and Boudier, Orr and Kuehn (1971) disagreed with Apinis' (1964) evaluation of M. thaxteri and they proposed to retain it as a separate species, Auxarthron thaxteri. Myxotrichum brunneum Rostrup was placed in synonymy with A. umbrinum (Boudier) Orr and Plunkett, but Auxarthron brunneum sensu Orr and Kuehn (1963a) was placed in synonymy with A. thaxteri since the description of this species was based on the type culture of M. thaxteri.

The perfect state of M. albolutea appears to fit the description of Orr *et al*. (1963a) of *A*. *thaxteri* [= *A*. *brunneum*]. Indeed, the perfect state of one of the strains examined by them (0-1024, UAMH 1117) is identical with the perfect state described here. However, an examination of the type strain of *A*. *thaxteri* (UAMH 3912, NRRL 1714, ATCC 15598, 0-532) and the description of Kuehn (1955b) revealed a number of differences from *M*. *albolutea*. First, the ascospores of the latter are globose, delicately roughened, (2.2) 2.5-3.5um in diameter, compared to the ascospores of *A*. *thaxteri* which are ovoid, delicately roughened, 2-2.2um x 2.8-3.2um (2.6-2.7um x 2.7-2.8um according to Kuehn, 1955b); the cleistothecia of both are similar in size and shape but the elongate appendages of *A*. *thaxteri* are shorter, 300-400um in length, and mostly uncinate; the arthroconidial state, *M*. *albolutea*, is prominent in early stages of growth, permitting recognition of this species, whereas the *Malbranchea* state of *A*. *thaxteri* is associated with the appearance of ascomatal initials in culture.

At present, the primary reason for not including the perfect state of *M*. *albolutea* in *A*. *thaxteri* is the difference in size and shape of the ascospores. Obviously, this difference in size is small and would normally be part of the range of variation for this species, but the shape of ascospores within a species should be uniform. Indeed, the ascospores of all isolates of *M*. *albolutea* are uniformly globose. The ascospores of *Auxarthron* species are not only globose or subglobose as suggested by Samson (1972) but also oblate and may be delicately roughened to spiny or echinulate-reticulate. For the present, the perfect state of _M_. _albolutea_ has not been assigned to _A_. _thaxteri_ nor has it been described as a new species, because the species of _Auxarthron_ should be reevaluated before additional ones are added.

Habitat and Activities

Recovered from soil or dung, in the USA, from Utah, Colorado, California and Wyoming and in Hungary.

_M_. _albolutea_ is keratinolytic, producing moderate digestion of hairs without the aid of penetrating bodies. Cellophane is not attacked.

Material Examined

From soil: UAMH 1117, Oildale, California, from Orr as O-1024; UAMH 2632, soil?, Cache la Poudre River, Colorado, by W.B. Cooke, 1965, from G. Barron, Ontario Agricultural College as 10527; UAMH 2846, TYPE, Utah, by G.F. Orr, 1967, as O-3508; UAMH 2848, fabric bait technique, Hungary, by G.F. Orr, 1967, as O-3515; UAMH 2861, Utah, by G.F. Orr, 1967, as O-3509; UAMH 3651, Wendover, Utah, from Orr as PO-0062; UAMH 3911, grasslands, Laramie, Wyoming, by M. Christensen (TC-22), from Orr as O-1030;

From dung: UAMH 1846, rat, Mercur, Utah, from Orr as 'Merc' (?O-1089);

Material of Auxarthron thaxteri: UAMH 3912, TYPE, dung of opposum shrew (Selenodon), Haiti, by R. Thaxter, from Orr as 0-532. (NRRL 1714, ATCC 15598)

Malbranchea arcuata Sigler et Carmichael sp. nov.

Description

Colonies on PYE (Fig. 10J) growing moderately slowly (13-30 mm at 14 days) are slightly raised with small central umbo or few large smooth folds across the surface. The center is tan, powdery, dry and cracked and the margin downy, creamy white and flatter, reverse yellow or yellowish tan. Colonies of some strains, growing more rapidly (45 mm in 14 days) are flatter, downy, creamy-white with pale tan center, reverse yellow, smooth or with few outward radiating folds. Growth at 37 C is variable. Of the five strains tested, four (UAMH 1861, 2519, 2570 and 3910) failed to grow, but the other (UAMH 2983) showed scant growth.

On cereal, colonies (Fig. 10K) grow moderately rapidly (23-40 mm in 14 days) and are tan, reverse buff, flat, powdery, in some strains appearing slightly zonate, in others, patchy. Scant brown pigment appears below the colony by 21 days. This brown pigment is also produced when strains are grown on oatmeal agar.

Arthroconidia borne on narrow arcuate or curved lateral branches (Fig. 10L), are cylindrical, often curved, smooth, hyaline at first, later tan, (1.5) 2-3um x 3-6um. Arthroconidia, formed by segmentation of the straight primary hyphae are hyaline, cylindrical, slightly broader, mostly 3um in diameter, and predominate in young cultures. In age, some arthroconidia become enlarged, subglobose or irregularly shaped (Fig. 10I).

No other spore state was observed.

Holotype: soil, Dugway, Utah, UAMH 1861 (0-1094, DPG 105)

Discussion

The tan powdery colonies and arthroconidia borne on arcuate hyphae are characteristic of *M. arcuata*. Some variation in colonial morphology and growth rates is evident among strains included in this species. However, there appears to be little justification for removing any to separate species since the microscopic morphology is uniform.

M. arcuata is distinguished from other *Malbranchea* species having buff or tan colored colonies, such as the *Malbranchea* state of *Uncinocarpus reesii* and *Malbranchea fulva*, by its arcuate hyphae. *M. aurantiaca* and *M. albolutea* differ in having orange colored and pale ivory yellow colored colonies respectively.

Habitat and Activities

Recorded from soil, dung of dog and birds, hair of rodents, USA and Yugoslavia (Hubalek, 1974a,b).

M. arcuata produced slight to moderate digestion of hairs without the aid of penetrating bodies. Cellophane is not attacked.

Material Examined

From soil: UAMH 1861, TYPE, Dugway, Utah, from Orr as DPG 105 (O-1094); UAMH 2519, Austin, Texas, by Alexopoulas, 1965, from Orr as Alex(50); UAMH 3877, ?dog dung, by Alexopoulas (50), from Orr as O-3263; ?UAMH 2570, mixed with plant debris, Columbia, South America, by A. Rostrepo, from C.W. Emmons, Dept. Health, Bethesda, Maryland, as B 27-40; From pellets of *Merops apiaster* in nest, Pesirevo, Yugoslavia: UAMH 3844, by Hubalek, 1968, as 232B; ?UAMH 3845, by Hubalek, 1968, as 236A; From hair of small rodents: UAMH 3847, Vojnik, Yugoslavia, by Hubalek, 1968 as JU 1623/2; UAMH 3902, *Apodemos* sp., Yugoslavia, by Hubalek (BH 14), from Orr as O-3411; From feathers: UAMH 3842, *Corvus monedula*, Purka, Yugoslavia, by Hubalek 1968, as 153A; From unknown sources: UAMH 2983, from R.S. Pore, West Virginia Univ. Medical Center, Morgantown as 704; UAMH 3910, from J. Ellis, NRRL 6089.

Malbranchea aurantiaca Sigler et Carmichael sp. nov.

Description

Colonies on PYE grow moderately rapidly (64-70 mm in 21 days) extending in spiral zones (Fig. 11A). The central zone is umbonate, dark yellow-gold or orange brown in color, velvety or powdery; succeeding zones vary from dark gold or yellow-orange to creamy white and floccose at the periphery, reverse dark orange. Continuing in a spiral pattern, the margin emerges beneath the outermost zone and gradually extends around the colony, at first white with scant aerial growth eventually creamy white, floccose and dense. Sometimes the zonate pattern is not as distinct but the characteristic color remains.

At 37 C growth on PYE (Fig. 11C) is almost as rapid (44-62 mm, rarely up to 72 mm in 21 days) flat with irregular folds, pale orange or tan, dark orange reverse, downy. Droplets of yellow or brown exudate occasionally form on the surface.

On cereal, colonies (Fig. 11B) grow slightly slower (53-62 mm in 21 days). In early stages, colonies are dome shaped, floccose and white and as sporulation commences, the center becomes flattened, dark yellow-gold, orange-brown or tan, powdery or granular, sharply demarcated from a peripheral floccose creamy white raised outer ridge (Fig. 11B). Two gradations can occur around the center with an inner region, pale tan or creamy white and floccose, slightly raised above the flat center. The reverse is yellow. A yellow pigment diffuses into the agar in some strains.

At 37 C, the colony (Fig. 11D) is characteristically slower growing (42-56 mm in 21 days) flat, dark tan or brown, powdery or granular, dense or patchy, with orange surface growth forming a distinct orange glabrous margin 5-8 mm wide. The reverse is light or dark orange.

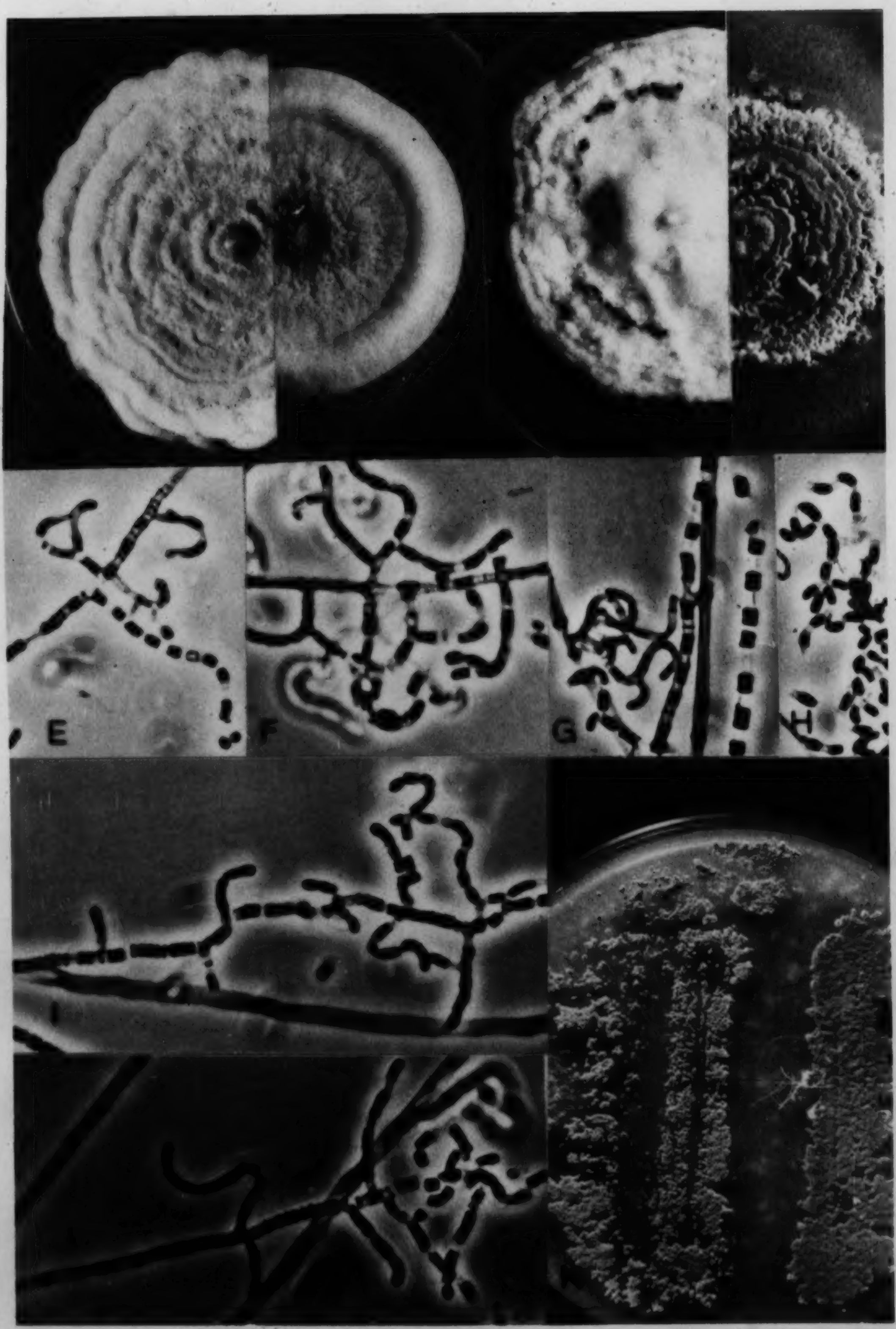
There is no growth at 45 C, the optimum range being 25-30 C.

Arthroconidia borne on narrow arcuate or curved lateral branches (Figs. 11E,11F) are cylindrical, often curved (Fig. 11H) hyaline at first, later orange or tan in mass, smooth 1.5-2um x (2)3-5.5(6)um. Arthroconidia formed on the straight primary hyphae (Fig. 11G) are hyaline, broader, cylindrical 3-4um x (2)3-7(7.5)um and predominate in young cultures. The development of racket hyphae is common in the primary hyphae with swelling at the septum up to 9um in diameter. Rarely, intercalary chlamydospores are seen.

a) Atypical strains (UAMH 1569, 1853, 1709, 2844)

Four strains differing in several characters have not been summarized in the description above. However, all four are indistinguishable microscopically (Figs. 11I,11J) from M. aurantiaca and they are retained here until similar isolates are found which would justify their removal to a separate species.

Figure 11. *Malbranchea aurantiaca* (A,B-UAMH 3704; C,D,H-1707; E,G-3599; F-3705; I,J-2844; K-1707x3599). Figs. 11A-11D. Colonial morphology after 21 days. A and C on PYE, B and D on cereal; C,D at 37 C, others at 25 C. Figs. 11E-11J. Alternate arthroconidia of curved branches and straight primary hyphae. Fig. 11K. Zone of inhibition in cross of 1707x3599 inoculated in separate parallel streaks. Colonies x 1.0, others x 830.


E
F
G
H
I

Two strains (UAMH 1569 and 1853) are identical to each other. These strains differ from typical strains in having paler yellow orange colored colonies and in lacking the distinct spiral zonate pattern. At 37 C growth is more restricted (22-33 mm on PYE and 7-14 mm on cereal in 21 days.

UAMH 2844 is similar to strains UAMH 1569 and 1853 in its yellow orange colored colonies. On PYE the colony is smooth, not zonate, domed with a central umbo and on cereal, it is flat with sparse aerial growth at the outer periphery and a raised more dense central zone. This strain differs from all others in growing more robustly and rapidly at 37 C (75 mm on PYE and 63 mm on cereal in 21 days).

Strain 1709 differs from the others in having slower growing (46 mm on PYE and 42 mm on cereal after 21 days), dark orange colonies, velvety or downy. On cereal, the colony is zonate with a central umbo and on PYE it is flat with broad white margin and central orange umbo. There is no growth at 37 C after 21 days. The arthroconidia are slighter broader, 2-3um in diameter. Late in the study we received another isolate (UAMH 3878) which greatly resembled UAMH 1709. These two strains may eventually require transfer to a separate species, but it seems preferable to retain them here until a larger number of isolates has been studied.

Holotype: lab plate contaminant, Dugway, Utah, UAMH 3599 (0-

1526)

Discussion

In its orange colored colonies, *M. aurantiaca* resembles the *M.* state of *Auxarthron conjugatum*. However, *A. conjugatum* is homothallic and regularly forms the perfect state in culture. Furthermore, the *M.* state of *A. conjugatum* does not develop the characteristic spiral zonate pattern on PYE, and growth at 37 C is much more restricted.

M. chrysosporoidea also forms orange colored colonies but lacks arcuate fertile hyphae. The color of the colony distinguishes *M. aurantiaca* from *M. arcuata* which forms buff colored colonies and *M. albolutea* which forms pale yellow or creamy white colonies.

Habitat and Activities

Occurrence: Isolated from soil or dung, India, Central America, Australia, USA and Belgium.

Mating tests: Crosses were performed in duplicate by each of the mixed suspension (method B) and parallel streak plate (method C) procedures (see Materials and Methods) with the addition of autoclaved human hair.

With a single exception, no cleistothecia were seen in any cross after 42 days. In the mixed suspension cross of UAMH 1707 x 3705 a single cleistothecium of the '*Auxarthron*' type (Orr, 1963a) bearing elongate uncinate appendages and few spiny oblate ascospores was seen. After a further two weeks growth no other cleistothecia were found nor were any discovered on the streak plate. The incompatibility of many of the strains was evident by a narrow or wide zone of inhibition on the streak plates (Fig. 11K, Table III).

Failure to obtain the perfect state in this species was surprising considering the close resemblance to some species of *Auxarthron* especially *A. conjugatum*. Indeed, several single ascospore isolates were attempted from a number of strains of *A. conjugatum* in the belief that *M. aurantiaca* might be the imperfect state of this species. However, all single ascospore isolates proved to be homothallic (see *Auxarthron conjugatum*).

The occurrence of a single fertile cleistothecium suggests either latent homothallism in one of the two strains tested or heterothallic incompatibility of the type frequently observed in some Gymnoascaceae. Incompatibility results in infertile crosses between F1 progeny and parent strains and between wild-type isolates crossed with each other or with tester strains of the opposite mating type. In the latter case, wild type isolates may only cross with the more fertile progeny of the parent strains (Kwon-Chung, 1971, 1972; Padhye and Carmichael, 1971, 1973).

Activity: *M. aurantiaca* produces moderate to marked

TABLE III
INCOMPATIBILITY AMONG CROSSES OF MALBRANCHEA AURANTIACA

STRAIN	1707	1709	1778	1853	2844	3524	3599	3660	3704	3705
1569	I	I	-	NI	-	-	NI	NI	-	-
1707		I	-	I	-	NI	I	NI	-	+
1709			NI	-	-	-	NI	I	-	-
1778				-	-	-	-	-	-	-
1853					-	-	NI	-	-	NI
2844						S	-	-	-	-
3524							NI	-	S	NI
3599								I	S	NI
3660									I	NI
3704										NI

Legend:

-	No cleistothecia formed on duplicate crosses
+	Single fertile cleistothecium formed on mixed suspension plate
NI	Narrow zone of inhibition (<3 mm) and no cleistothecia
I	Moderate zone of inhibition (>3 mm) and no cleistothecia
S	Zone of stimulation at interface of mating strains

digestion of hairs but fails to attack cellophane.

Material Examined

From soil: UAMH 1569, chicken feeding ground, Tonasi, Panama, collected H.P. Puri, isolated by G.F. Orr, as O-2505; UAMH 1705, garden, Tonasi, Panama, by G.F. Orr, O-2535; UAMH 1707, chicken feeding ground, Tonasi, Panama, by G.F. Orr, O-2531; UAMH 1709, South California, by G.F. Orr, O-584; UAMH 1710, pig yard, Tonasi, Panama, by G.F. Orr, O-2534; UAMH 1778, from mixed culture received as 288c (soil, Guatemala) from Orr; UAMH 1853, Australia by Warcup, from Orr as O-3598 (A 270/1); UAMH 2844, Belgium, by De Vroey, 1966, from Orr as O-3178; UAMH 3660, from Ellice Island, Alaska, from Orr as O-3035; UAMH 3818, Italy, by Varsavsky (I36) from Orr as O-3437; UAMH 3878, Inogmar area, California, from Orr as O-683; O-3482, Somalia, by DeVroey (RV 20443) from Orr; O-2592, Panama, from Orr; From dung: UAMH 3483, mouse, India, from Orr as O-3150; UAMH 3524, rat, India, from Orr as O-3733 (NRRL A-19283); UAMH 3704, rat, India, from Orr as O-1163; UAMH 3053, lizard, Chihauhua, Mexico, by R.K. Benjamin, 1964, RSABG, as 1468; From other sources: UAMH 3599, TYPE, plate contaminant, Dugway, Utah, by G.F. Orr as O-1526; UAMH 3705, plate contaminant, Dugway, Utah, by G.F. Orr as O-3214; UAMH 3879, hair from ringworm lesion on horse, Riverton, Utah, from Orr as O-3710

8

Malbranchea chrysosporoidea Sigler et Carmichael sp. nov.

Description

Colonies on PYE (Fig. 12A) growing rapidly (66-83 mm in 21 days), are characteristically bright tangerine orange, reverse orange. Nonsporulating floccose areas at the center or periphery are white or pale yellow. Colonies are dense, powdery or velvety, slightly raised, with a central domed downy or floccose umbo, scarcely zonate, demarcated by 2 or 3 changes in color from dark orange at the center to a light ~~or white~~ periphery, or distinctly zonate with 6 or 7 concentric zones. The margin, crenate or entire, develops scant aerial hyphae closely adpressed to the cellophane, then becomes floccose, white or pale orange. No pigment is apparent but most strains formed yellow, orange or white exudate droplets.

At 37 C, growth on PYE is more restricted (Fig. 12C) (25-31 mm in 21 days) adhering poorly to the cellophane, with the center lifting up, becoming convoluted or folded, with new growth appearing below. The center turns dark tan, brown, or tawny, powdery and with new growth, downy, orange. If the colony remains firmly attached to the cellophane, the diameter reaches to 44 mm and the colony is orange buff in color.

Colonies on cereal (Fig. 12B) growing slightly more slowly (61-68 mm in 21 days) are flat, mostly with a small central umbo, powdery or granular, patchy or dense, often sectoring, scarcely zonate with changes in color from dark orange or tawny to yellow at the periphery, reverse orange.

At 37 C, growth is slower (18-36 mm in 21 days) orange or buff, rarely white, granular or downy, flat with a brown pigment appearing below the colony (Fig. 12D).

Fertile hyphae bearing arthroconidia are of two types. Straight, slightly broader, branched primary hyphae, 2-4um in diameter, which first produce intercalary arthroconidia (Figs. 12E,12F) and later form multiple straight or curved, deflexed lateral branches (Fig 12E,12I) bearing intercalary arthroconidia intergrading with aleurioconidia formed terminally or directly on the sides of the hypha. The width of the arthroconidia and aleurioconidia forming on the same hypha are identical with the diameter of the hypha. Intercalary arthroconidia are cylindrical-truncate, hyaline, later pale orange, orange in mass, (1.5)2-4um x (2)3-9(13)um. Aleurioconidia are smooth, hyaline, later pale orange, orange in mass, cuneiform 2-3um x (2.5)3-5.5(6.5)um.

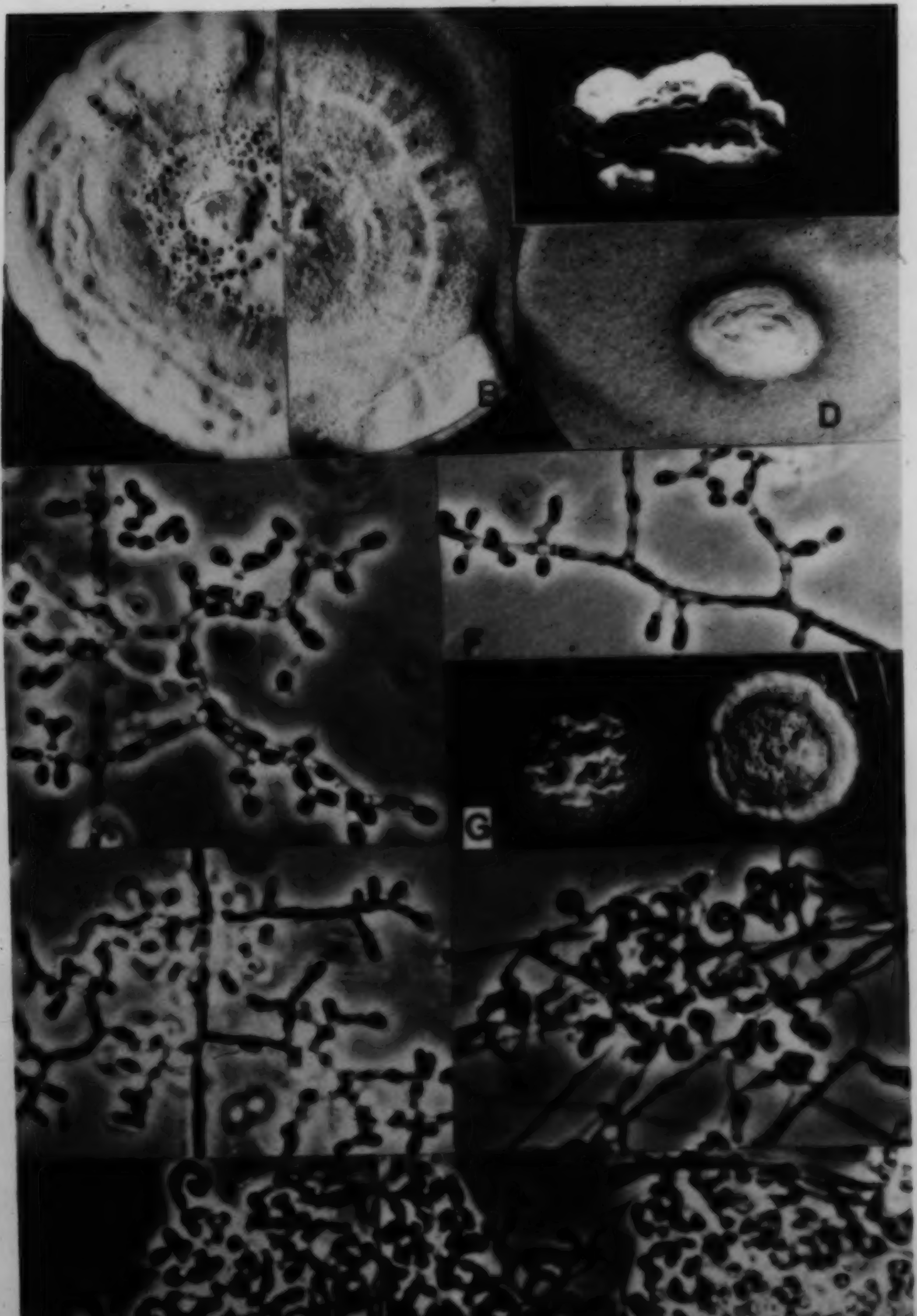
No other spore state was observed.

Holotype: soil, Arizona by C.W. Emmons (E5003), UAMH 1032 (0-1525)

Discussion

This species is a form intermediate between *Malbranchea* and *Chrysosporium*. Though formation of aleurioconidia is

Figure 12. A-F, I. Malbranchea chrysosporoidea (A-D-UAMH 1032; E,F,I-1031). G,H,J-M. Malbranchea circinata (G-H,J,M-1890; K,L-3589). Figs. 12A-12D. Colonial morphology after 21 days. A and C on PYE, B and D on cereal. C and D at 37 C, others at 25 C. Figs. 12E-12F. Aleurioconidia and intercalary arthroconidia. Figs. 12G-12H. Colonial morphology after 21 days at 25 C. G on PYE, H on cereal. Fig. 12I. Lateral or terminal aleurioconidia and intercalary arthroconidia. Figs. 12J-12M. Coiled sporogenous hyphae. Colonies x 0.9, others x 830.


B
D
F
G

characteristic of Chrysosporium, arthroconidia may predominate in degenerate strains. The aleurioconidia of Chrysosporium are mostly subglobose, pyriform or clavate, and wider in diameter than the supporting hypha. Though this distinction appears somewhat arbitrary, it is difficult to assign this species with assurance to either Malbranchea or Chrysosporium. However, for the moment, several characters favor its placement in Malbranchea: the diameter of the aleurioconidia and intercalary arthroconidia does not exceed the diameter of the supporting hypha; intercalary arthroconidia predominate in the primary hyphae, consistent with other species of Malbranchea; the diameter of the fertile hyphae fits well within the rather narrow range for Malbranchea. Interestingly, too, vivid orange colored colonies occur in at least three other species of Malbranchea, whereas most Chrysosporium colonies are white or light colored, green, brown, grey, buff, occasionally pale orange or orange-buff.

Habitat and Activities

Recorded from soil, dung or air samples, Maryland, Utah, Hawaii, Arizona, South Carolina, California (Orr, 1970, 1972), Japan and India. One strain was recovered from omental abscesses and the spleen after experimental intraperitoneal inoculation of soil into mice.

Keratin is digested slightly or not at all. Cellophane is not attacked.

Material Examined

From soil: UAMH 1031, Arizona, by Emmons (E5002), from Orr as 0-1524 (same strain as UAMH 2786?); UAMH 2786, omental abscesses in mice inoculated with soil, Bethesda, Maryland, by Emmons (E5002), 1958, from Kwon-Chung, National Institute of Health, Bethesda; UAMH 1032, TYPE, Arizona by Emmons (E5003), from Orr as 0-1525; UAMH 2288, bean garden, Shokuku, Japan, by G.F. Orr; UAMH 2740, India, from H.C. Gugnani, National Institute of Communicable Disease, New Delhi, as S536; UAMH 3570, S. Carolina, from Orr as 0-3517; UAMH 3876, Oahu, Hawaii by Varsavsky (9) from Orr as 0-3295; Soil isolates from Orr: 0-3224, Maui, Hawaii, by Varsavsky (7); 0-3377, California?, by Varsavsky (20); 0-3381, Kauai, Hawaii, by Varsavsky (18); 0-3398, Oahu, Hawaii, by Varsavsky (21); 0-3399, Maui, Hawaii, by Varsavsky (25); From other sources: UAMH 1060, coyote dung, Kern Co., California, by G.F. Orr as 0-837 (NRRL A-10663); UAMH 1241, plate contaminant, Edmonton, 1962; UAMH 2051, Hawaiian Islands, soil?, from Varsavsky, CDC, as KAVAI-18; UAMH 2850, wind tunnel contaminant, Utah, by G.F. Orr 1967, as 9BR5; UAMH 3856, spore mass, Dugway, Utah, from Orr as 0-3077; NRRL 6087, from J.J. Ellis

Malbranchea circinata Sigler et Carmichael sp. nov.

Perfect State: Myxotrichum Kunze

Description

Colonies on PYE (Fig. 12G) are slow growing (29 mm in 21 days), pale creamy yellow, with floccose tufts of hyphae at the center surrounded by a wide (4-8 mm) band of slimy tufted surface growth. The reverse is yellow.

On cereal, colonies (Fig. 12H) attain the same diameter, but growth is more luxuriant, dense, velvety, smooth with a narrow slimy margin. The color is dark gold, reverse yellow. Droplets of brown exudate appear near the center and extend to the periphery, gradually drying and leaving the surface pitted. A reddish brown pigment diffuses into the medium extending well beyond the margin of the colony by 21 days.

There is no growth at 37 C and growth at 18 C and 30 C is slower than at 25 C.

The sporogenous hyphae (Figs. 12J-12L), arising as lateral branches somewhat broader in diameter than the narrow vegetative hypha which bears them, are tightly coiled or curved, closely spaced, eventually forming a dense cluster (Fig. 12M). Arthroconidia are smooth, cylindrical, curved, kidney shaped or ovate, almost discoid in end view, pale yellow, or yellowish brown, in age purple or dark yellow-green, 2-3um x 3-5um. No arthroconidia develop on the primary hyphae.

Cleistothecia (Fig. 13A) are dark brown, almost black, discrete, 350-450um in diameter, excluding appendages, spherical but tending to coalesce, not easily dislodged from the conidiogenous hyphae. Peridial hyphae are dark brown, thick walled, smooth, continuously branched, terminating in 'antler-horn' appendages (Figs. 13A,13C-13E) with narrow delicate branchlets (Figs. 13C,13D), pointed toward the perimeter. Appendages of a second type are uncinate (Figs. 13A,13C), sparingly septate, thick, smooth walled, 100-200um long, 5-7um wide at the tip and the same diameter or slightly narrower at the base. The uncinate appendages arise at the center or near the periphery from a bifurcate base with the other branch terminating in the 'antler-horn' appendage (Fig. 13C).

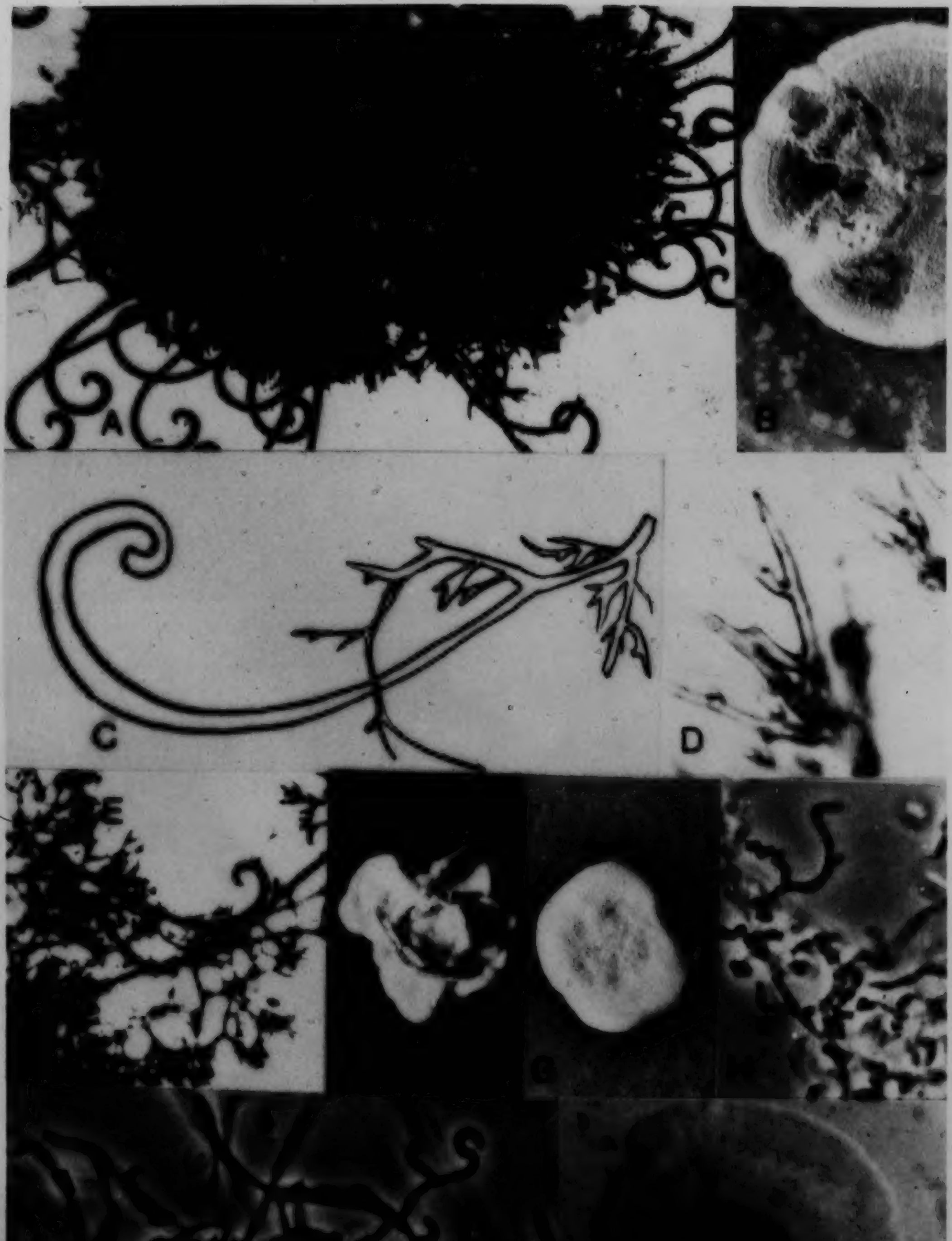
No ascospores were found. When the cleistothecium is crushed, yellow-green or purple coiled conidiogenous hyphae in the centrum give the impression of asci, and the mature kidney shaped or ovate conidia can be mistaken for ascospores. However, the size should distinguish the arthroconidia.

Holotype: soil, Dugway, Utah, UAMH 1890 (0-1103, DPG 111)

Discussion

The formation of cleistothecia corresponded to sectoring of the colonies on oatmeal agar at 25 C

Figure 13. A-E. Malbranchea circinata (A-UAMH 3589; B-E-1890). F-J. Malbranchea flavoroseus (F-H-1051; I,J-1065). Fig. 13A. Cleistothecium bearing uncinate appendages, x 210 BF. Fig. 13B. Sectoring on oatmeal agar after 35 days at 30 C, x 1.0. Fig. 13 C. 'Antler-horn' and uncinate appendages, x 660. Fig. 13D. 'Antler-horn' appendages, x 1320 BF. Fig. 13E. Coalescing peridial hyphae appendages of both types, x 210 BF. Figs. 13F-13G. Colonial morphology after 21 days at 25 C, x 0.9. F on PYE, G on cereal. Figs. 13H-13I. Curved fertile hyphae bearing alternate arthroconidia, x 830. Fig. 13J. Cleistothecia (minute black specks) formed at the center and near the periphery after 42 days at 25 C on oatmeal agar, x 0.9.


A
B
C
D
E
G

(Fig. 13B). Indeed, cleistothecia consistently formed along the interface of the sector, which was white with sparse aerial growth and glabrous margin, compared to the remainder of the colony which was yellowish brown, powdery and dense with abundant conidial formation. Transfers from the sector to fresh oatmeal agar produced a colony degenerate in appearance with scant aerial growth and pale color. Coiled conidiogenous hyphae were less abundant. Transfers from the powdery yellow brown portion yielded colonies similar in appearance in which sectors eventually appeared. Asexual sporulation was profuse in the powdery areas. A transfer of a single cleistothecium yielded again a sectoring colony developing cleistothecia along the interface. Formation of cleistothecia in sectors has also been recorded for atypical colonies of *M. stipitatum* (Orr *et al.*, 1963b).

Attempts to stimulate ascospore production by mating were unsuccessful, although only two isolates were available. Both isolates required the presence of the cellophane membrane for cleistothecia to occur. None were found on the agar alone.

It is difficult to relate this species to any *Myxotrichum* species already described, especially in the absence of ascospores. Our cultures of *M. carminoparum* Robak (Orr *et al.*, 1963b) (UAMH 1597 and 1906) also have failed to produce ascospores, but this species differs in its conidial state, lacking the coiled conidiogenous hyphae of *M*. *circinata*, and in its colonial morphology. At 25 C, the colony of the type strain (UAMH 1597, CBS 224.31) is sparse and restricted and the observation of Orr *et al*. (1963b) of growth at 7 C ± 2 C suggests a lower optimum temperature for growth.

The peridial hyphae of *M*. *chartarum*, 'witches-broom-like' in appearance (Orr *et al*., 1963b) is somewhat similar but the terminal branchlets are more spiny and less delicate in appearance. Here again, the coiled conidiogenous hyphae are absent, though *M*. *chartarum* has an arthroconidial imperfect state.

Habitat and Activities

Recorded only from soil, Utah (Orr and Kuehn, 1972).

M. *circinata* digests cellophane but fails to attack keratin. Hairs sprinkled on DSA become purple in color after three weeks from the diffused pigment.

Material Examined

UAMH 1890, TYPE, soil, Dugway, Utah, from Orr as 0-1103 (DPG 111); UAMH 3589, soil, Terra, Utah, from Orr as 0-3225 (DPG 118)

Malbranchea *flavoroseus* Sigler et Carmichael sp. nov.

Perfect state: *Myxotrichum* Kunze

Description

Colonies on PYE grow moderately slowly (29-32 mm in 21 days) adhering poorly to the cellophane so that the margin lifts up and curls toward the center to form a distinct petaloid pattern (Fig. 13F). The margin is lobate ~~with new~~ growth extending unevenly beneath the raised perimeter. Colonies are creamy white, buff in the center, reverse dark tan in the center, yellow at the periphery, velvety.

On cereal, colonies (Fig. 13G) are the same diameter, flatter, pinkish buff in color and floccose. A dark brown pigment diffuses into the agar below the colony.

On oatmeal agar, colonies (Fig. 13J) become deep rose pink in the center with paler pink margin, floccose, crateriform. Growth is optimum at 25 C with slightly slower growth at 18 C and 30 C. Cleistothecia form most abundantly at 18 C, developing at the center and close to the periphery (Fig. 13J).

There is no growth at 37 C; the optimum range is 25-30 C.

Arthroconidia developing on short, loosely curved or arcuate lateral branches (Figs. 13H,13I) are cylindrical, often curved, hyaline, smooth, 1.5-2um x 3-5um. In age, arthroconidia become swollen, rounded or subglobose.

Cleistothecia are spherical, approximately 400-600um, discrete, black (Fig. 14A), composed of a network of smooth, thick walled, septate dark brown peridial hyphae, 5-6um in diameter, having blunt tips and lateral bluntly pointed spines along the length deflexed at an acute angle toward the center (Fig. 14B). The blunt tipped ends of the peridial appendages extend 120-200um beyond the densely branched center (Fig. 14A). No other appendages are formed. Asci and ascospores were not observed.

Holotype: soil, Riverside County, California, by G.F. Orr,
UAMH 1051 (0-643)

Discussion

Neither of the two strains studied developed ascospores even after prolonged growth and multiple transfers. Attempts to cross the two isolates were unsuccessful. A third strain (UAMH 3909, NRRL 6088) received late in the study also failed to develop ascospores. No isolation data was provided with this strain, but it was deposited by G.F. Orr in NRRL. It could be the same strain as either UAMH 1051 or 1065.

The perfect state of this species is assigned to Myxotrichum primarily on the basis of its dark brown peridial hyphae. In the absence of ascospores, a specific epithet has not been chosen, nor can the isolates be assigned with certainty to any known species. Although superficially resembling Myxotrichum deflexum Berkeley (Ann. Nat. Hist. 1:260, 1838), this species differs in several respects. First, the cleistothecia are much larger, 400-600um, compared to 100-400um for M. deflexum (Orr et al, 1963b; Apinis, 1964); the appendages of M. deflexum are narrow 1.4-1.8um (Orr et al., 1963b) or up to 3um (Apinis, 1964) in diameter with lateral branches, deflexed either upward or downward, having hyaline blunt apices, whereas those of this species are wider, 5-6um in diameter, with lateral bluntly pointed spines, brown in color, branched consistently downwards (Fig. 14B); finally, a conidial state has not been observed for M. deflexum (Orr et al., 1963b; Apinis, 1964).

Other characters of this species are also common to Myxotrichum. Orr et al. (1963b) reported cessation of growth at 37 C for all Myxotrichum species, characteristic reddish brown diffusing pigments, and pink or reddish colored colonies for some species. Pink or reddish colored colonies are notable in M. aeruginosum, M. deflexum and M. stipitatum. In addition, this species is cellulolytic, as are other species of Myxotrichum.

Habitat and Activities

The two isolates were recovered in California, one from soil, the other from lung of kangaroo rat.

Both strains are cellulolytic after several weeks.

Material Examined

UAMH 1051, TYPE, soil, Riverside Co., California, by G.F. Orr as 0-643; UAMH 1065, lung, kangaroo rat, Palo Verde, California, from Orr as 0-647; UAMH 3909 (NRRL 6088)

Malbranchea pulchella Saccardo et Penzig 1882
Michelia 2:638

Synonyms

= *Malbranchea bolognesii-chiurcoi* Vuillemin, Pollacci et Nannizzi 1925, in Bolognesi et Chiurco, Archivi di Biologia 1:255-276

  = *Actinomyces bolognesii-chiurcoi* (Vuill. *et al.*) Dodge 1935, Medical Mycology p. 766

= *Malbranchea kambayashii* Kambayashi 1934, Archiv fur Dermatologie u. Syphilis 170:97-106

History

Saccardo (1882) described *Malbranchea* with a single species *M. pulchella* Saccardo et Penzig, reiterating his description in 1886. Saccardo (1908) and Saccardo and Trotter (1913) reduced Miehe's (1907) thermophilic *Thermoideum sulfureum* to synonymy with *M. pulchella*.

Two other species were described, *M. bolognesii-chiurcoi* Vuillemin, Pollacci and Nannizzi in Bolognesi and

Chiurco (1925) and *M. kambayashii* Kambayashi (1934). Though we have not seen the original descriptions, Baldacci, Ciferri and Vaccari (1939) reviewed both and reduced them to synonymy with *M. pulchella* based on a comparison of cultural and microscopic characteristics of four isolates: *M. pulchella* of Buisman, *M. bolognesii-chiurcoi* of Bolognesi and Chiurco (1925) and Rivelloni (1938), and *M. kambayashii* of Kambayashi (1934). With the exception of the Rivelloni strain which showed scant growth, all failed to grow at 37 C. Furthermore, the authors could find no reason to justify Dodge's (1935) transfer of *M. bolognesii-chiurcoi* to *Actinomyces*.

Elisei (1940a) in a similar comprehensive examination of *Malbranchea*, reviewed the literature and also studied the same four isolates. Elisei, revising the genus, concurred with Saccardo (1908) in placing *T. sulfureum* in synonymy with *M. pulchella*. Elisei also observed a number of microscopic features not previously recorded including nodular organs, spiral hyphae, and pectinate bodies. The latter were reviewed again by Elisei (1940b) in comparison to some dermatophytes.

Few reports of other *Malbranchea* species are cited in the literature. In 1913, Sumstine transferred *Rhinotrichum pulveraceum* Ellis to *Malbranchea* as *M. pulveracea*. Linder (1942) disagreed and proposed the combination *Oidium pulveraceum* because the conidia were borne in chains on short denticles. Clamp connections on the hyphae indicate that this species is a conidial state of the genus *Botryobasidium* of the Basidiomycotina or a related genus.

Cooney and Emerson (1964) studying a thermophilic isolate of *Malbranchea* proposed a new variety *M. pulchella* var *sulfurea*. However a number of characters differentiate the mesophilic *M. pulchella* from the thermophilic isolates suggesting that the latter should be included in a separate species.

More recently, Wang (1965) again described and illustrated a mesophilc *Malbranchea pulchella* isolate from a pulp sample.

Von Arx (1970) stated that *Malbranchea* included 3 or 4 species, but named only *M. pulchella*.

Description

Colonies on PYE (Fig. 14C) growing moderately slowly (26-33 mm in 21 days) are flat, or adhere poorly to the cellophane membrane, so that the center or the margin detaches and lifts up with new growth extending below. The margin is entire, or lobate and undulate. Colonies are white or mostly tan or pale brown, reverse tan or yellow, downy or velvety in texture. Creamy white exudate droplets occasionally form on the surface.

On cereal, colonies (Fig. 14D) attain a similar diameter (20-30 mm in 21 days) but remain more firmly attached to the cellophane. In appearance, colonies are tan, white or buff, reverse pale or dark tan or yellow, flat with a central umbo and few outward radiating folds, or dome shaped, downy or velvety. Droplets of white or brown exudate sometimes form on the surface, and a brown pigment diffuses into the agar below.

Good growth occurs at 30 C but there is no growth at 37 C.

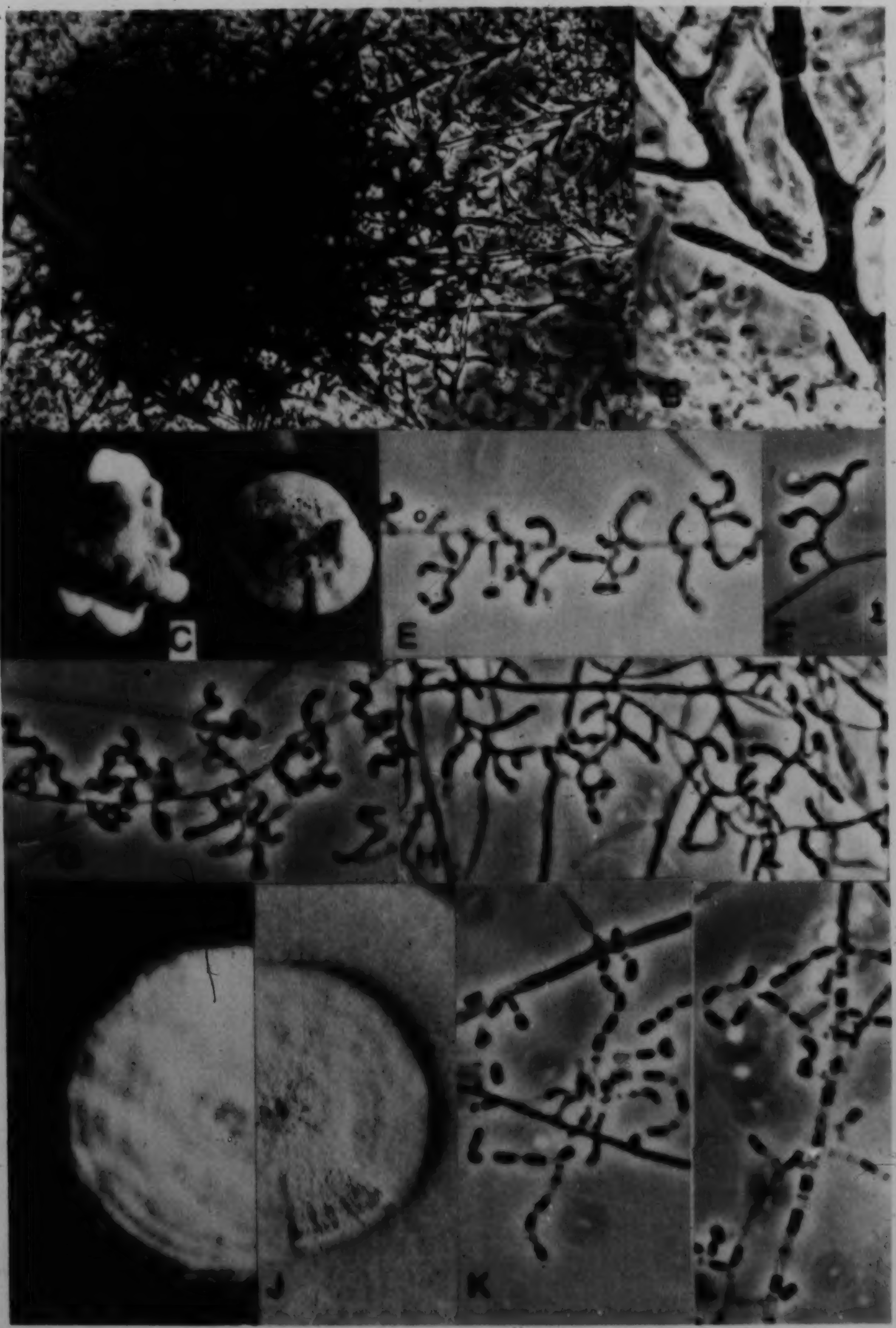
Fertile hyphae, arising as short lateral branches from the narrow (1-2um wide) vegetative hyphae form multiple branches which are tightly coiled, arched, or curved (Figs. 14E-14H). Arthroconidia are cylindrical, curved, hyaline, in mass tan, smooth 1.5-3um x 2-6.5um, mostly 1.5-2.5um x 2.5-5um. Accessory arthroconidia are rarely formed by segmentation of the primary hyphae.

Typical strain: from pulp sample at paper towel mill,
N. Y. State, 1959, by C.J.K. Wang, UAMH 1560

Discussion

Considerable variation was initially evident among isolates received as *M. pulchella*. Based on Saccardo's measurement of the conidia as 3 x 2.5um as well as examination of photomicrographs from a slide (DAOM 41374) of the type, some of these isolates have been excluded (see *Malbranchea flocciformis* and *M. flavoroseus*). Arthroconidia

Figure 14. A-B. _Malbranchea_ _flavoroseus_ (UAMH 1051). C-H. _Malbranchea_ _pulchella_ (C,D,F,G,-1560; E,H-3189). I-L. _Malbranchea_ state of _Auxarthron_ _conjugatum_ (I,J-3817; K,L-3156). Fig. 14A. Cleistothecium composed of dark brown peridial hyphae. Fig. 14B. Peridial hypha with deflexed lateral spines. Fig. 14C-14D. Colonial morphology after 21 days at 25 C. C on PYE, D on cereal. Fig. 14E-14H. Coiled or curved sporogenous hyphae. Fig. 14I-14J. Colonial morphology after 21 days at 25 C. I on PYE, J on cereal. Fig. 14K-14L. Alternate arthroconidia of curved branched and straight primary hyphae. Colonies x 1.0, others x 830, except A, x 210.


B
C
E
F
1
H
J
K

of DAOM 41374 measure 1.5um x 2-4um. Of those remaining, UAMH 3794 (strain Kambayashi) differs from the others in forming slightly larger arthroconidia (2.5-3um x 4.5-6um) and wider primary hyphae (3um wide) which fragment to form accessory arthroconidia. However, this strain resembles the others in colonial morphology and failure to grow at 37 C.

UAMH 3783 (strain Rivelloni) failed to grow at 37 C although Baldacci _et al_. (1939) reported slight growth. Also the size of the arthroconidia, 2.5-3um x 3.5-6.5um differs slightly from the measurements given by them (3-4um x 6.5-7.5um), but variations could be expected in view of the prolonged maintenance of this isolate. Indeed, Cooney and Emerson (1964) reported no sporulation at all. In UAMH 3907 (strain _M_. _bolognesii-chiurcoi_), production of arcuate fertile hyphae was weak. However, this strain was initially contaminated with bacteria and at first, failed to sporulate at all. When freed of contamination, sporulation occurred after prolonged growth on cereal agar. However, this strain appears to be somewhat degenerate. Baldacci _et al_. (1939) reported arcuate hyphae in the type strain of _M_. _bolognesii-chiurcoi_.

None of these three strains corresponds exactly with the typical strain. However, all three more closely resemble _M_. _pulchella_ than any other species described herein.

In general, the following characters distinguish _M_.

pulchella from other species: buff or tan slow growing colonies, no growth at 37 C, lack of accessory arthroconidia and presence of cellulolytic activity.

Habitat and Activities

Occurrence: Reported from cardboard (Saccardo, 1882) and pulp (Wang, 1965), USA, wallpaper, and human sources in Italy, China, Sardinia (Baldacci et al., 1939; Cooney and Emerson, 1964). Hubalek, Balat, Touskova and Vik (1973) and Hubalek (1974a,b) isolated M. pulchella from nests and feathers of birds in Czechoslovakia and Yugoslavia.

Pathogenicity: Cooney and Emerson (1964) in discussing the pathogenicity of the human isolates noted that experimental inoculation by Vuillemin, Pollacci and Nannizzi into white rats, and by Kambayashi into guinea pigs reaffirmed the pathogenicity of their isolates. However, similar experiments by Rivelloni were unsuccessful in demonstrating pathogenicity.

Activity: M. pulchella digests cellophane after several weeks. A single strain (UAMH 3189) also digested keratin slightly with single hyphae penetrating the hair.

Material Examined

UAMH 643 and 1191, photomicrographs of slide (DAOM 41374) of TYPE, wet cardboard; UAMH 1560, from pulp sample at a paper towel mill, N.Y. State, 1959, by C.J.K. Wang, State University of N.Y., Syracuse; UAMH 3189, card, Gravesend, England, by P. Russell (BS421), 1954, from CMI as 57206; UAMH 3783, CBS 204.38, from Ciferri as 'ceppo Rivelloni'; UAMH 3794, from CBS 203.38, from Ciferri as *M. kambayashii*, 1938; UAMH 3909, from CBS 202.38, from Ciferri as *M. bolognesii-chiurcoi*, 1938

Malbranchea state of *Auxarthron conjugatum* (Kuehn) Orr et Kuehn in Orr *et al*. 1963a, Can. J. Bot. 41:1452

History

Orr *et al*. (1963a) transferred *Myxotrichum conjugatum* Kuehn (1955b) to *Auxarthron*. De Vroey (1970) referred to a new species of *Auxarthron* isolated from soil in Burundi and his fig. 39 indicates a resemblance to *A. conjugatum*.

Description

Colonies on PYE (Fig. 14I) grow moderately rapidly (46-59 mm in 21 days) and are pale yellow orange or orange-buff, reverse dark orange, dry, powdery, cracked or powdery near the center with downy, creamy white overgrowth and periphery. If mostly powdery, the colony is flat with central downy umbo, otherwise zonate with 7-8 outer zones including the margin.

On cereal, colonies (Fig. 14J) are orange-buff in color, flat, powdery or with downy creamy white to pale orange pleomorphic overgowth, reverse light to dark orange. Cleistothecia form near the center of the colony.

Growth at 37 C is slow (7-9 mm at 14 days); the colonies are pale orange, heaped up, downy, or velvety, reverse tan or orange.

Arthroconidia borne on narrow lateral arcuate branches (Figs. 14K, 14L) are cylindrical, curved or straight, smooth, hyaline, in age pale orange, 1.5-2um x 2.5-5um. Arthroconidia formed by segmentation of the broader, straight hyphae (Fig. 14L) are 3 x 3-5um in diameter, often becoming swollen, rounded or subglobose in age (Fig. 15A).

This species is homothallic, and the perfect state has been described in detail by Orr and Kuehn (in Orr *et al.*, 1963a).

Discussion

In early stages of growth, the *Malbranchea* state of *Auxarthron conjugatum* closely resembles *M. aurantiaca*. The *Malbranchea* states are difficult to differentiate, both forming orange colored colonies, and having arcuate fertile hyphae and arthroconidia of a similar size range. Indeed, in order to determine the relationship between the two species, strains of *M. aurantiaca* were crossed, and single ascospore isolations of several *A. conjugatum* strains were attempted. However, single ascospore isolates from five strains (UAMH 3130, 3156, 3516, 3517, and 3519) of *A. conjugatum* were consistently self-fertile. The sexual crosses of *M. aurantiaca* were negative with the exception of one cross, UAMH 1707 x 3705 (Table III) which formed a single cleistothecium having elongate appendages and containing few spiny, oblate ascospores (see *Malbranchea aurantiaca*).

In their original description of *Auxarthron conjugatum* Orr and Kuehn (1963a) noted that elongate appendages were straight, hooked or coiled, rarely branched. However, apical branching of elongate appendages (Fig. 15B) occurred frequently in all strains of *A. conjugatum* when cultured on a variety of media, including cereal, oatmeal and DSA agar. A single cleistothecium, in addition to branched elongate appendages, also bore some which were unbranched, straight or hooked at the apex.

Orr and Kuehn (1963a) reported that ascospores of *A. conjugatum* were spherical or ovoid, asperulate, smooth when young but becoming asperulate in age. Our examination indicates that the ascospores are oblate (Figs. 15C,15D), 1.5-2.2um x 2.5-3.2um and very finely roughened. In all strains examined, the asperulate nature of the ascospores is almost beyond the resolution of the phase contrast light microscope. Even at high magnification (x2700), the finely roughened edge of the ascospore is barely discernible

(Figs. 15C,15D). Scanning electron microscopy would be required to resolve the exact nature of the ascospore surface.

Habitat and Activities

Recovered from soil, dung, feathers and lungs of rodents, in the USA, from Arizona, California, Kansas, and from Australia, Mexico, India and the Sudan (Orr *et al*., 1963a).

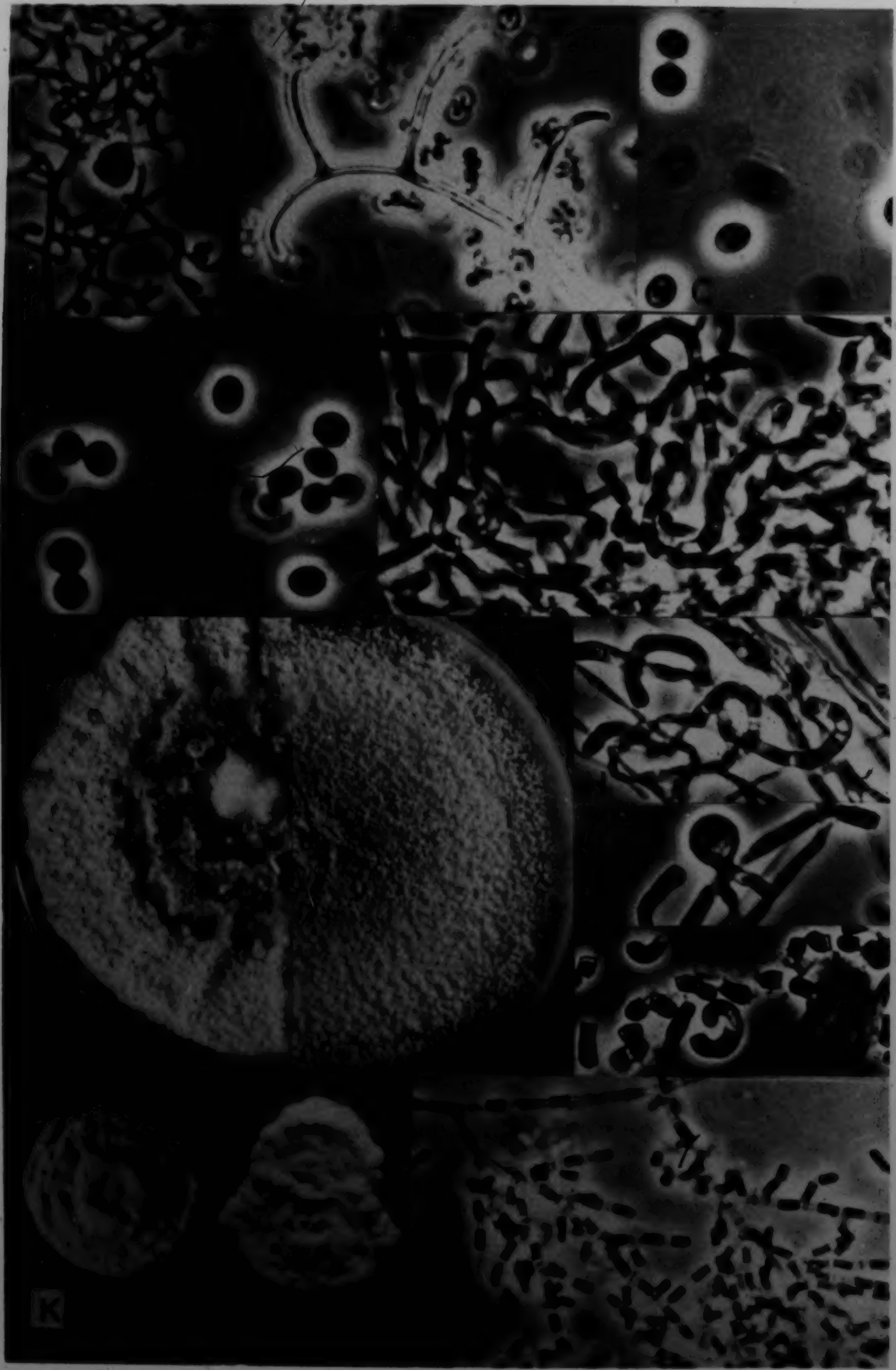
A. conjugatum is keratinolytic, producing slight to moderate digestion of hairs without the aid of penetrating bodies. Cellophane is not attacked.

Material Examined

From soil: UAMH 3156, TYPE, Arizona, by C.W. Emmons (47), from R.K. Benjamin, RSABG as 1530 (NRRL 1244, 0-520); UAMH 3516, Sudan, received from L. Ajello, CDC as 32 b; UAMH 3517, Sudan, from L. Ajello, CDC as 32 a; UAMH 3519, Sudan, from L. Ajello, CDC, as 28 a; UAMH 3817, India, by Ghosh, from Orr as 0-1236; UAMH 3874, Kansas, from Orr as 0-3750; From other substrates: UAMH 3130, lizard dung, Chihuahua, Mexico, by R.K. Benjamin, 1964, RSABG as 1474; UAMH 3841, feathers (domestic fowl), Australia, by Rees, from Orr as 0-3153 (F91)

Malbranchea sulfurea (Miehe) Sigler et Carmichael

Figure 15. A-D. *Auxarthron conjugatum* (A,B,D-UAMH 3156; C-3817). E-J. *Malbranchea sulfurea* (E,I,J-2485; F,G-3748; H-2486). K-M. *Malbranchea dendritica* (2731). Fig. 15A. Enlarged arthroconidia and curved sporogenous hyphae. Fig. 15B. Apical branching of elongate peridial appendage. Figs. 15C-15D. Oblate, finely asperulate ascospores. Fig. 15E. Alternate arthroconidia borne on curved or coiled branches. Figs. 15F-15G. Colonial morphology after 7 days at 45C. F on PYE, G on cereal. Fig. 15H. Curved sporogenous hyphae. Fig. 15I. Thick walled chlamydospore. Fig. 15J. Thick walled mature arthroconidia. Figs. 15K-15L. Colonial morphology after 21 days at 25 C. K on PYE, L on cereal. Fig. 15M. Branching at an acute angle of fertile hyphae. Colonies x 1.0, others x 830, except C and D, x 2300.


K

comb. nov.

Synonyms

= Thermoideum sulfureum Miehe 1907, Deutsche Botanische Gesellschaft 25:515 (Basionym)

= Malbranchea pulchella var sulfurea (Miehe) Cooney et Emerson 1964, Thermophilic Fungi p. 102

History

In 1907, Miehe created a new genus and species Thermoideum sulfureum for a fungus he found growing on spontaneously heated compost heaps. By studying the fungus in culture, Miehe not only established the thermophilic nature of the organism but also accurately illustrated and described the formation of conidia. According to Miehe, the curved fertile hypha divided itself into short segments, which later developed an internal thickened membrane to form the spore. In the process, not all the cells became spores, but only alternate ones. Saccardo (1908) and Saccardo and Trotter (1913) reduced Thermoideum sulfureum to synonymy with M. pulchella without regard for the thermophilic nature of the organism.

Elisei (1940a) examining four mesophilic strains, followed Saccardo (1908) in placing T. sulfureum in synonymy with M. pulchella.

In 1964, Cooney and Emerson reviewed the history of

Malbranchea and provided an excellent account of the morphology of a thermophilic strain isolated by Emerson in 1945. Their fungus corresponded in appearance to the description of the thermophilic Thermoideum sulfureum of Miehe (1907). A comparison with the study of Baldacci et al. (1939) of four mesophilic isolates indicated that these organisms differed at least in temperature relations. Cooney and Emerson examined a single mesophilic strain (strain Rivelloni) which failed to sporulate and they were unable to make a definite distinction between the thermophilic and mesophilic isolates. Therefore they proposed a new variety for the thermophilic isolates, Malbranchea pulchella var sulfurea (Miehe) until a more comprehensive comparison of the mesophilic and thermophilic strains could be made.

An examination of a number of isolates indicated that the thermophilic strains are distinct from the mesophilc M. pulchella and therefore a new combination is proposed here.

Description

At 45 C, colonies (Fig. 15F) on PYE grow rapidly and robustly, almost or completely filling the petri dish by 7 days, and becoming dense and thick, smooth or with few outward radiating folds, velvety with coarse, creamy yellow tufts of hyphae over the surface. The color is sulfur yellow or yellowish tan, with yellow or pink margin, turning by 21 days to a dark gold or buff brown or deep reddish brown color. Large droplets of dark brown exudate appear on the surface by 7 days (Fig. 15F), gradually drying and leaving the surface of the colony pitted and mealy in appearance. The medium turns dark brown or black from diffused pigment. At 37 C, growth is slightly slower (70-78 mm in 7 days) characteristically sulfur yellow in color with darker tan center, and otherwise similar in appearance to colonies at 45 C. Pigment production is slightly reduced at 37 C.

At 45 C, colonies (Fig. 15G) on cereal attain a diameter of 79-81 mm by 7 days, and are sulfur-yellow, flat, coarse, and mealy with tufts of yellow hyphae. Initial yellow exudate droplets later turn dark brown and when dried, leave the colony pitted. By 21 days, the colony turns dark tan or reddish brown, in appearance a dense, thick mat, smooth often with few irregular folds, and velvety. Diffused pigment turns the medium dark brown in color. Growth at 37 C is slightly slower, but otherwise similar. The color at 21 days is dark reddish brown. Pigment production appears slightly reduced.

Degenerate or less robust strains (UAMH 2481, 2486, and CBS 423.54) are greenish grey or drab grey in color, glabrous, hairy or leathery with scant aerial growth. The pigment exceted into the medium is much reduced.

The arthroconidia are borne on curved or loosely coiled lateral branches (Figs. 15E,15H) arising from broader vegetative hyphae (3-6um in diameter). The vegetative hyphae are hyaline, later yellowish brown with prominent racket hyphae, the enlargement at the septum reaching a diameter of 9um or more. In some strains, thick walled intercalary or terminal chlamydospores (Fig. 15I) formed, increasing in abundance at 45 C. Arthroconidia (Fig. 15J) are cylindrical, often curved, thick walled, often with attached hyaline frill from the outer hyphal wall of the separating empty cell, hyaline at first, later yellow, tan or yellowish green (2)2.5-4(4.5)um x (3)3.5-7.5(8.5)um, mostly 3-4um x 4-7um.

Discussion

Cooney and Emerson (1964) and Awao and Otsuka (1973) provide further accounts of the morphology of this species.

M. sulfurea differs from M. pulchella in its thermophilic nature, its colonial morphology, its broader vegetative hyphae and its thick-walled broader arthroconidia. In its capacity to grow at high temperature, M. sulfurea is distinct from all other species of Malbranchea. Furthermore, chlamydospores are formed regularly.

No other spore state was observed and attempts to mate the isolates by pairing them on oatmeal agar at 37 C in 3% CO2 were unsuccessful.

Habitat and Activities

Occurrence: Numerous records of M. sulfurea from heated substrates indicate that this species is ubiquitous and has a world wide distribution.

M. sulfurea has been reported from plant heaps and rotting plant material: guayale rets, California (Cooney and Emerson, 1964); composting heaps, Germany, Texas (Miehe, 1907; Rode, Foster and Schuhardt, 1947); wheat straw compost, England (Chang and Hudson, 1967) and stacked tobacco leaves, South Africa (Eicker, 1972). It has been isolated from soil in Japan (Awao and Otsuka, 1973); peanut kernals and associated soil, Texas (Taber and Pettit, 1975); coal spoil tips, England (Evans, 1971); faeces of Cape sparrow, South Africa (Eicker, 1972); dung of deer, Japan (Minoura, Yokoe, Kizima, and Nehira, 1973) and cattle, Alberta; hen-house litter, Netherlands; snuff, USA, (Tansey, 1975) and from air sample surveys, England (Hudson, 1973).

M. sulfurea is notably absent from self-heating wood chip piles (Shields, 1969; Tansey, 1970 (Abstract), 1971b; Smith and Ofosu-Asiedu, 1972).

Growth rates: Table IV compares maximum diameters of colonies of M. sulfurea tested at five temperatures. Growth occurred at 25 C, albeit slowly, and at 55 C for all isolates tested.

TABLE IV
DIAMETER (MM) OF AGAR PLATE COLONIES OF MALBRANCHEA SULFUREA AFTER GROWTH AT DIFFERENT TEMPERATURES

Temperature (°C)	25[1]	30[1]	37[2]	45[2]	55[2]
Time (days)	28	35	7	7	7
2481	+	75	78	90	N
2485	+	30	73	90	42
2486	+	66	72	90	N
3747	+	23	74	80	26
3748	+	16	77	80	10
3761	N	N	N	N	32
3788	N	N	N	N	42
3789	N	N	N	N	25

Legend:
+ Scant growth (diameter of colony < 5 mm)
N Not tested
1 Growth tested on oatmeal agar only
2 Growth tested on PYE agar

The minimum temperature is close to 25 C, the maximum 55-57 C (Cooney and Emerson, 1964). Chapman (1974), studying the effects of temperature on growth rates of several thermophiles, concluded the optimum for _M_. _sulfurea_ was 40-45 C, with no growth at 30 C or 55 C after 8 days.

Cellulolytic Activity: _M_. _sulfurea_ attacks cellophane vigorously, markedly weakening the membrane by 21 days.

Chang (1967) reported growth on xylan, the major hemicellulose of straw, when provided as the sole carbon source, but no utilization of cellulose in the form of filter paper, a finding confirmed by Fergus (1969). Fergus (1969) demonstrated the use of carboxymethyl cellulose by _M_. _sulfurea_. Tansey (1971a) measured the zone of clearing of acid swollen cellulose in an agar medium. Though _M_. _sulfurea_ produced a definite clearing, indicating cellulolytic activity, the zonal front was indistinct and difficult to measure. Tansey suggested that a portion of the system of enzymes required for digestion of cellulose could be lacking, thereby rendering the organism incapable of attacking insoluble cellulose.

Metabolites: Rode _et_ _al_. (1947) identified an antibiotic from _M_. _sulfurea_ as comparable in activity to authentic penicillin.

Ong and Gaucher (1973), examining a number of thermophiles, characterized intracellular and extracellular proteases, one of which, the extracellular alkaline protease of _M_. _sulfurea_ has been defined by Voordouw, Gaucher and Roche (1974) as thermomycolase, a thermostable protease, protein in nature.

Lipids: Mumma, Fergus and Sekura (1970), studying the lipid composition of some thermophilic and mesophilic fungi, revealed a difference in the degree of saturation of fatty acids, measured by the number of double bonds per mole of fatty acid. The thermophiles, in comparison to mesophiles of the same genus, were found to be more saturated _i_._e_. have fewer double bonds per mole. Crisan (1973) pointed to the higher melting point of the saturated fatty acids as a factor in the thermostability of these organisms, and discussed lipid stability as one of four hypotheses explaining thermophilism in fungi. However, Crisan considered the best explanation of thermostability resided in the basic ultrastructure of the organism, possibly in the integral genetic make-up, the cell structure or the ribosomes.

Mumma _et_ _al_. (1970) finding a higher lipid composition for _M_. _sulfurea_ than some other thermophiles suggested the difference was due to extraction of the soluble pigment.

Material Examined

UAMH 3761, NEOTYPE, from retting _Parthenium_ _argentatum_, Salinas, California, by Emerson (27), 1945, from CMI as 126327; From ensiling alfalfa hay forage: UAMH 2481, isolated 1953, received from Semeniuk, South Dakota State University, Brookings as 401; UAMH 2485, 1953, from Semeniuk as 422; UAMH 2486, 1953, from Semeniuk as 459; From dung: UAMH 3747, manure in cattle feedlot, Lethbridge, Alberta, by R.G. Bell, 1974, Research Station, Lethbridge as 1; UAMH 3748, manure in cattle feedlot, Lethbridge, by R.G. Bell, 1974, as 2; UAMH 3789, deer dung, Hiroshima, Japan, by K. Minoura, 1970, from Tubaki, IFO, as 9739; From other substrates: UAMH 3827, soil, hen-house litter, by A.H.M. Grimbergen, from CBS as 343.55; UAMH 3857, seed of _Oryza sativa_, China, from CBS as 115.68; UAMH 3858, from CBS as 960.72; CBS 423.54

b) _Malbranchea_ species with straight fertile hyphae

Malbranchea dendritica Sigler et Carmichael sp. nov.

History

During a search for _Coccidioides immitis_ in California soil, Plunkett, Walker and Huppert (1963) isolated three fungi which produced arthroconidia from acutely branched hyphae, giving a "pine-tree appearance" to the sporulation in slide culture. They inoculated three mice intraperitoneally with each strain and killed them after 10, 15 and 20 days. Small nodules were found in all mice, but no endosporulating spherules were seen. "When planted on media, these nodules yielded colonies that were identical to the original culture. Isolates from tissue were prepared for inoculation into a second group of five mice. On the 7th day after inoculation all mice revealed endosporulating spherules at autopsy and established the identification as C. immitis. The cultures recovered from the mice were again identical to the original one." Despite the discrepancy between the results of the first and second sets of mouse inoculations, they identified their isolates as atypical Coccioides immitis.

Huppert, Sun and Bailey (1967) studied a collection of 301 strains of fungi which would grow on media containing cyclohexamide. They stated that for each strain endosporulating spherules had been demonstrated in mice inoculated intraperitoneally, and the fungus recovered in culture. Thus, they identified all their strains as C. immitis, regardless of their colonial and microscopic morphology. Details of the animal inoculations were not given. Some of their isolates (strain numbers not given) had acutely branched fertile hyphae and their Figure 6 shows the microscopic morphology which we now consider to be characteristic of M. dendritica. Their Figure 7 shows a Malbranchea similar to M. gypsea (q.v.).

Orr (1968) isolated a dendroid Malbranchea from soil. Later (Orr, 1972) he compared the pathogenicity of this isolate (UAMH 2731, DPG-141) with several other isolates of *Malbranchea*, including strains of *M. gypsea* and with *Coccidioides immitis*. Passage of each organism though mice resulted in lesions in the spleen and liver but no endosporulating spherules were observed in mice other than the ones inoculated with *C. immitis*. In addition, histopathological examination revealed no fungal elements, although the arthroaleuriospore formers could be recovered in culture from the tissue. *Malbranchea dendritica* was recovered from the lungs in addition to the spleen and liver and survived four serial passages though mice. Control mice inoculated with physiological saline were negative.

It appears probable that the three isolates of Plunkett *et al*. (1963) and some of the atypical *Coccidioides immitis* strains of Huppert *et al*. (1967) should be included in *Malbranchea dendritica*.

Description

The colony on PYE (Fig. 15K) is moderately slow growing, reaching a diameter of 31 mm in 21 days, creamy buff, reverse buff, rising to a central plateau, velvety. On cereal (Fig. 15L), the colony reaches a diameter of 37 mm in 21 days and is white, reverse white, slightly raised with scarcely distinct zonate pattern, velvety.

Growth at 37 C is slow. On PYE, the colony is 23 mm in diameter, white, heaped up and convoluted, velvety. The edge of the colony detaches from the cellophane membrane. On cereal, the colony is 20 mm in diameter, flat at the periphery but cerebriform in the center, waxy, pale buff in color.

The fertile hypha, branched at an acute angle from the primary hypha (Fig. 15M) is straight, bearing multiple short or long lateral branches. Branching occurs consistently at an acute angle giving the fertile hypha a tree-like appearance (Fig. 16A). Arthroconidia are first formed on the apical part of the main axis of the fertile hypha and on the lateral branches (Fig. 16B). Later, the base of the hypha and the primary hypha become regularly septate, followed by separation into arthroconidia. Arthroconidia are separated by one or more empty segments, a single segment often shorter than the length of an arthroconidium. Arthroconidia are hyaline, smooth, cylindrical 1.5-2(3) um x 3-5um.

Holotype: soil, Dugway, Utah by G.F. Orr, UAMH 2731 (DPG-141)

Discussion

The regularly acute angle of branching of the fertile hyphae distinguishes M. dendritica from all other species of Malbranchea.

Habitat and Activities

The single strain examined was recovered from soil, Utah.

M. dendritica is keratinolytic, producing moderate digestion of hairs without the aid of penetrating bodies.

Malbranchea flava Sigler et Carmichael sp. nov.

Synonym

?= *Malbranchea* state of *Oncocladium flavum* Wallroth 1833, Flor. Crypt. German. p. 289

History

In 1900, A. L. Smith, described *Gymnoascus verticillatus*, characterized by brown thick-walled verticillate peridial hyphae and globose ascospores, 2.5um in diameter, separate or in ascus-like groups. In 1963, Orr and Kuehn described *Actinodendron verticillatum* based on Smith's description and an examination of her type specimen, HERB BM, by Stockdale and Balfour-Browne. Because of its verticillate peridial hyphae, the fungus was considered distinct from *Gymnoascus* Baranetzky. Though Smith (1900, 1901) apparently did not attempt pure cultures, Orr and Kuehn (1963) reported several recent isolations of the fungus, by Szathmary in Hungary, Plunkett in California, and Stockdale in Wales. However, the verticillate hyphae observed in the original specimens could not be reproduced in culture. Also, neither asci nor ascospores were observed in the specimens of Szathmary and Plunkett. Several fungi were isolated from Plunkett's hair bait sample (all designated OAP- 19-317), two of which had arthroaleuriospore states. Orr and Kuehn (1963) suggested that a keratin source such as hair may be required for cleistothecial development.

Apinis (1964) reviewing Actinodendron verticillatum, examined several specimens, including Smith's type material, Stockdale's specimen from sheep's wool (HERB IMI 100,300), an isolate of his own from a dead bird, and one from feathers placed in a damp chamber (HERB K). In the latter material, Apinis observed asci and ascospores as well as the characteristic appendages in older brown clusters formed on the feathers. Also associated was a conidial state consisting of conidia resembling the aleurioconidia of Chrysosporium merdarium and the arthroconidia of Geotrichum and also endogenous microconidia. Apparently, Apinis did not attempt to make pure cultures from the feathers.

Subsequently, Hughes (1968) comparing the type specimen of Oncocladium flavum Wallroth, a Hyphomycete, with the type specimen, HERB BM, of Actinodendron verticillatum, concluded the verticillate hyphae in both were identical. In the specimen of O. flavum, Hughes observed neither asci nor ascospores, nor any conidia of the Chrysosporium type, but reported an arthroconidial state resembling Oidiodendron. According to Hughes, the verticillate hyphae were characteristic of *Oncocladium*. Since Wallroth's original description did not refer to ascospores, Hughes considered *Oncocladium flavum* to be the conidial state of *Actinodendron verticillatum*. He also suggested that *Oncocladium* could prove to be an earlier name for *Oidiodendron*.

The taxonomic position of *Actinodendron verticillatum* was complicated by Orr and Kuehn (1971) who accepted Hughes' appraisal of *O. flavum* as a Hyphomycete, and proposed rejection of *A. verticillatum* since ascospores had not been observed in any but Smith's type specimen. Apparently, they failed to examine the two specimens reported by Apinis (1964) to have ascospores. Orr and Kuehn (1971) concluded that the verticillate hyphae were structures of the Hyphomycete *Oncocladium* and that the ascospores present in Smith's type material were not part of the same fungus.

Based on these conflicting reports, it is difficult to assess the true nature of *Oncocladium*. On the one hand, there is Apinis' assertion that ascospores are present in clusters bearing verticillate hyphae, and on the other, there is Orr and Kuehn's (1971) rejection of *Actinodendron*. While both Orr and Kuehn (1963) and Szathmary (1967b) reported verticillate hyphae in keratin-baited samples, to our knowledge, neither has induced their formation in culture. However, the list of cultures of *Oncocladium flavum* examined by Orr and Kuehn (1971) includes isolates from Plunkett's hair bait sample (OAP-19-317, miscitation

OAP-19-1317) (Orr and Kuehn, 1963) as well as several arthroaleuriospore formers corresponding in appearance to isolates described as *Gymnoascus verticillatus* by Szathmary (1967a,b).

In specimens we have examined, HERB IMI 100,300 of Stockdale, and HERB IMI 100,445, a few spiny, oblate ascospores were observed in the latter. The label on the specimen indicated *Anixiopsis stercoraria* [= *Aphanoascus fulvescens*] to be present. Conidia of the *Chrysosporium* type and the appearance of the ascospores agree with *A. stercoraria*, although no cleistothecia were observed. In any case, the appearance of the ascospores did not agree with the description of Smith (1900) and Apinis (1964). No ascospores were observed in the two slides of IMI 100,300.

In both specimens, however, an arthroconidial state is present within the clusters bearing verticillate hyphae (Figs. 16C,16D). Pseudocleistothecia or peridial appendages have been observed in culture in some heterothallic Gymnoascaceae, notably *Ctenomyces serratus* (Benjamin, 1956), *Uncinocarpus reesii*, and some *Myxotrichum* and *Arthroderma* species (Varsavsky and Ajello, 1964; Padhye and Carmichael, 1973; Sekhon, Padhye and Carmichael, 1973). The peridial hyphae of the pseudocleistothecium resemble those of the fertile cleistothecium, but the structure, devoid of asci and ascospores, contains only conidia. According to Benjamin (1956), the presence of infertile cleistothecia confused the taxonomy of Ctenomyces serratus Eidam for many years. Eidam described Ctenomyces as having two stages, a fertile cleistothecial state and a sclerotial or resting state. However, Benjamin (1956) showed that the specimen examined by Eidam contained two different fungi, the first, Arthroderma curreyi and the second Ctenomyces serratus. No ascospores were reported by Eidam for the sclerotial state but Benjamin (1956) retained the name Ctenomyces serratus for the fungus distinguished by the characteristic comb-like appendages.

The infrequent occurrence of ascospores in Oncocladium suggests that the fungus may be heterothallic requiring mating of compatible strains before fertile cleistothecia are formed. It seems probable that the verticillate hyphae arise as thick walled extensions of the vegetative hyphae, forming clusters on the natural substrate, but remaining infertile unless compatible mating types are present. In the Malbranchea state of Uncinocarpus reesii uncinate appendages, arising as extensions of the vegetative hyphae also intertwine to form a cleistothecium when compatible strains are mated.

The verticillate hypha of Oncocladium flavum is narrow at the base, but becomes wider at the apical or distal end, terminating in a blunt tip and occasionally extending into a hyaline septate hyphal appendage which gradually narrows to a diameter of 2-3um (Fig. 16C). The branchlets forming the verticils are pointed at first then become blunt tipped as the apical segment detaches. In this respect, the hyphae resemble the peridial hyphae of some Myxotrichum species which often terminate in blunt spines, the terminal portion having broken off.

For the present, the true nature of the association of the appendages with the arthroconidial state is not definitely established. Though Hughes (1968) has suggested Oncocladium flavum is a Hyphomycete characterized by verticillate hyphae, it appears to us more likely that these hyphae are peridial appendages of the perfect state. If so, the name Oncocladium could be retained for the perfect state since the key feature of Oncocladium, as Hughes (1968) noted, is the verticillate hyphae. The arthroconidial state, clearly distinct from Oidiodendron is assigned to Malbranchea.

Description

Growth on PYE (Fig. 16F) is moderately rapid with the diameter at 21 days varying from 39-61 mm. Colonies are lemon yellow with darker gold center, occasionally sulfur yellow, greenish yellow, or creamy white, powdery, rarely woolly, dense, dry, separating and lifting from the cellophane in the center and becoming undulate with folds extending to the margin. The center and outer folds develop deep cracks or splits as the colony ages. The colony

(Fig. 16E) appears zonate at first as the advancing margin extending 1-3 mm beyond the perimeter turns from white to yellow and becomes floccose.

Growth on cereal is more restricted (26-39 mm in 21 days), appearing (Fig. 16G) flat, straw yellow in color with a darker gold center, rarely white, coarse, powdery, or woolly. A wrinkled, waxy small umbo with tiny surrounding cracked furrows, develops at the center in some strains. A slight amount of yellow pigment diffuses into the agar below the colony.

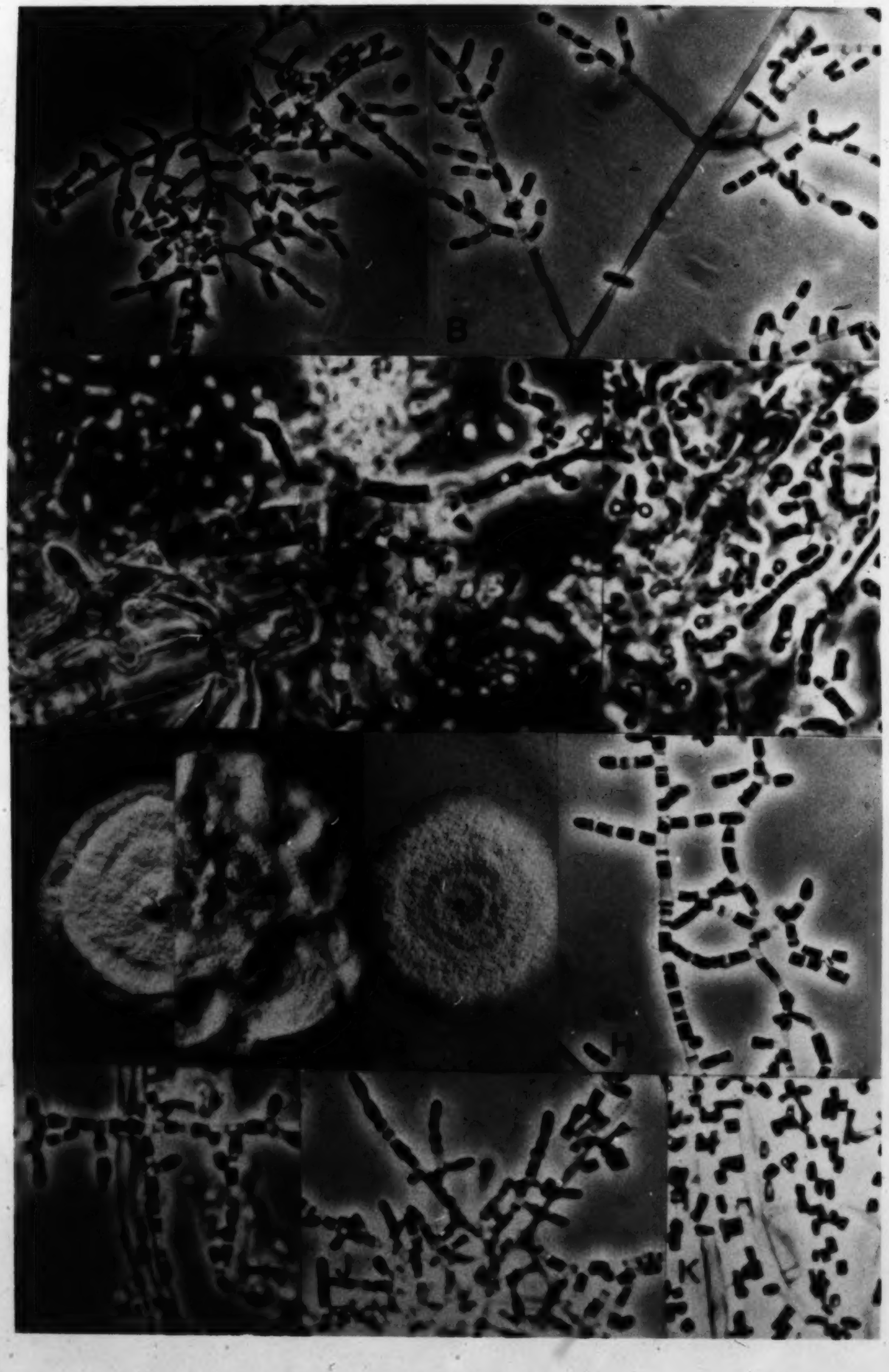
30 C is close the maximum for growth, with only a single strain (UAMH 1879) showing growth after 5 weeks (10 mm). The optimum range is 18-25 C.

Arthroconidia developing on straight, branched fertile hyphae (Figs. 16H-16J), are separated from each other by one or more empty segments (Fig. 16H) which are divided by thickened septae suggesting double septae (Figs. 16H,16I). The arthroconidia are cylindrical, cuneiform if terminal, discoid in end view, hyaline, later greenish yellow, often with refractile end walls (Fig. 16K), 2-3um x 2-6um, mostly 2-3um x 2.5-5.5um. Clamydospores are rare.

No other spore state was observed.

Holotype: soil, South California, by O.A. Plunkett, 1962,
UAMH 1589 (OAP 19-317)

Figure 16. A-B. *Malbranchea dendritica* (UAMH 2731). C-D. *Oncocladium flavum* (IMI 100300). F-K. *Malbranchea flava* (E,J,K-2864; F,G-1589; H-1956; I-1879). Figs. 16A-16B. Tree-like appearance of branched fertile hypha. Fig. 16C. Blunt tipped verticillate hypha with hyaline terminal appendage (arrows). Fig. 16D. Verticillate appendage and associated arthroconidial state. Figs. 16E-16G. Colonial morphology at 25 C. E and F on PYE, G on cereal. E at 14 days, F and G at 21 days. Figs. 16H-16J. Alternate arthroconidia of branched fertile hyphae. Fig. 16K. Arthroconidia with refractile end walls. Colonies x 1.0, others x 830.


A
B
H
K

Habitat and Activities

Recorded from soil, California, Hungary and France (Szathmary, 1967a,b; Orr and Kuehn, 1963, 1971).

Most isolates of *M. flava* showed only slight digestion of hairs without penetration of the hair by hyphae. Two strains (UAMH 1879 and 1956) did not attack hair at all. This limited capacity to digest hair *in vitro* is interesting since most were isolated by keratin-bait techniques. In addition, the requirement for a keratin source has been suggested as a prerequisite for cleistothecial formation (Orr and Kuehn, 1963).

Material Examined

Soil isolates received from Orr: UAMH 1589, TYPE, California, by O.A. Plunkett, 1962, OAP-19-317; UAMH 1879, California, by O.A. Plunkett, OAP-19-317(6); UAMH 1956, Argentina, Varsavsky, EV 5V (0-3596); UAMH 2859, Tunis, by De Vroey, RV 19535a (0-3496); UAMH 2860, Tunis, sector of RV 19535a, by Orr, as RV 19535b; UAMH 2864, fabric-bait, Hungary, Szathmary, 1967, 0-3512; UAMH 2865, fabric-bait, Hungary, Szathmary, 1967, 0-3514;

Material of *Oncocladium flavum*: HERB IMI 100,300, sheep's wool on dung, Wales, by P.M. Stockdale, 1962 (UAMH 3920); HERB IMI 100,445, wool, associated with *Anixiopsis stercoraria* (UAMH 3921)

Malbranchea flocciformis Sigler et Carmichael sp. nov.

Description

Colonies on PYE (Fig. 17A) grow moderately slowly (22-42 mm in 21 days) adhering poorly to the cellophane, and lifting off the membrane at the margin or at the center with the margin depressing the medium. In appearance, colonies are domed with deep folds or convolutions, or petaloid, pale or tangerine orange, reverse tan, and downy or velvety. Exudate droplets occasionally form near the center.

On cereal agar, colonies (Fig. 17B) are somewhat flatter, (24-38 mm in 21 days) either dome shaped with the margin depressing the medium and downy, or crateriform, zonate and powdery. The color is pale or tangerine orange or pale yellow. A single strain (UAMH 675) formed yellow exudate droplets on the surface and a brown pigment below the colony.

With the exception of UAMH 3273, which showed scant growth (5 mm in 21 days on PYE) the isolates did not grow at 37 C.

Arthroconidia are borne on the primary hyphae (Fig. 17C) and on short or long lateral branches (Figs. 17C,17D) which often branch repeatedly to form a dense tuft (Fig. 17E). The fertile hyphae are characteristically straight, occasionally curved (Fig. 17F).

Arthroconidia are cylindrical, hyaline or pale yellow, orange in mass, smooth (1.5) 2-2.5um x 2-5.5um.

Holotype: from briny soil, Chateau-Saline, Lorraine, France, UAMH 3273

Discussion

Two of the strains included here were initially determined to be M. pulchella. Of the two, UAMH 675 resembles M. pulchella in its curved fertile hyphae (Fig. 17F) but differs in forming accessory arthroconidia on the primary hyphae and in having orange colored colonies. Although UAMH 675 may not be suitably placed in this species, it is retained here until further isolates are reported.

Habitat and Activities

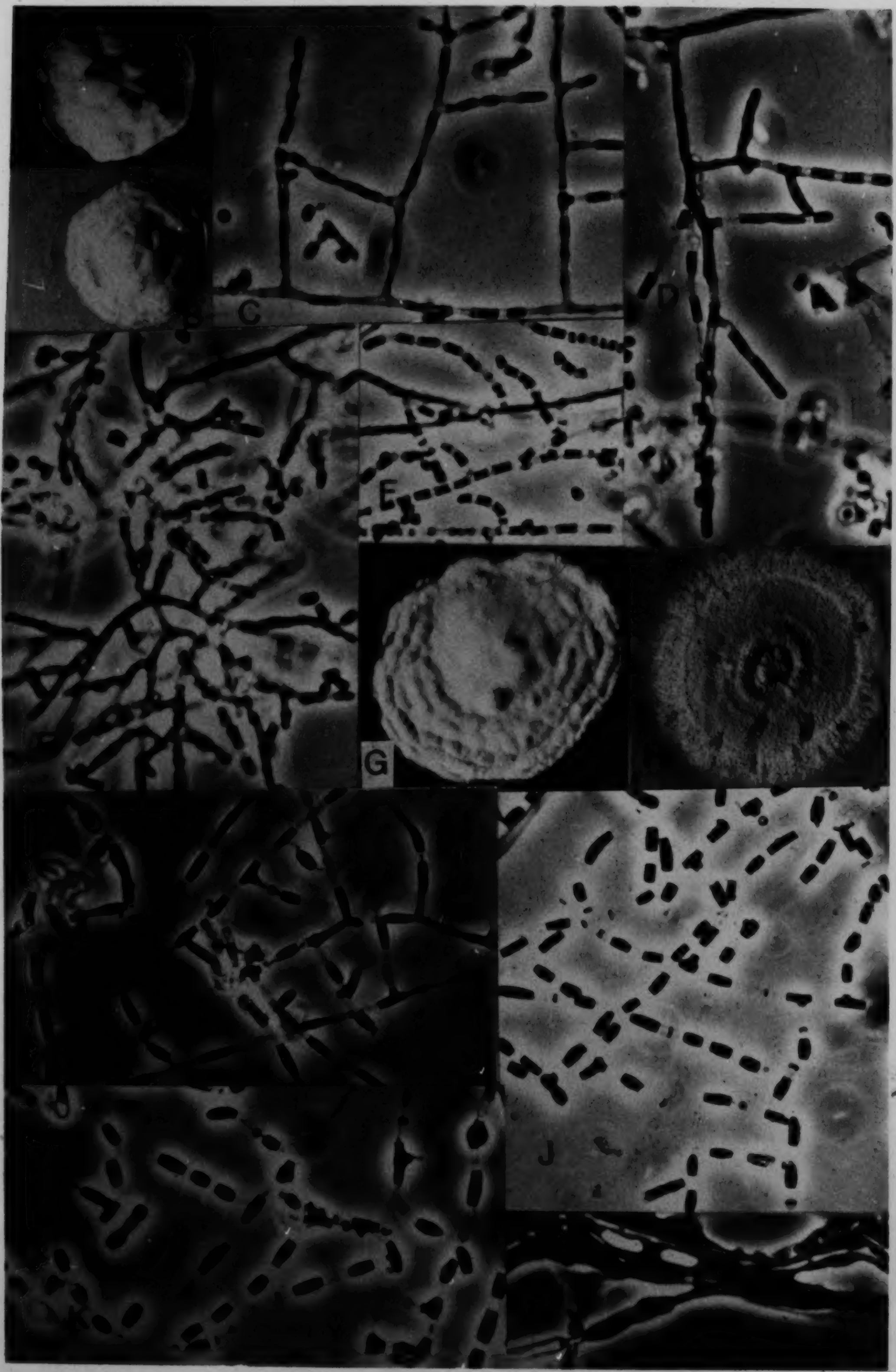
Recovered from briny soil, France and wood of a lemon bin, California.

M. flocciformis digests cellophane after prolonged growth and is slightly keratinolytic.

Material Examined

UAMH 675, wooden lemon storage bin, California, by P.B. Harding, 1959, from DAOM as 64000 (CMI 96741); UAMH 3273, TYPE, briny soil, Chateau-Saline, Lorraine, France, from J. Nicot, Laboratoire de Guffbogaurie, Paris; UAMH

Figure 17. A-E. _Malbranchea flocciformis_ (A-E-3273; F-675). G-L. _Malbranchea fulva_ (G,H-2851; I-1708; J-2849; K,L-3729). Figs. 17A-17B. Colonial morphology after 21 days at 25 C. A on PYE, B on cereal. Figs. 17C-17D. Alternate arthroconidia borne on straight primary hyphae and lateral branches. Fig. 17E. Repeated branching of fertile hyphae. Fig. 17F. Slightly curved sporogenous branches. Figs. 17G-17H. Colonial morphology at 21 days at 25 C. G on PYE, H on cereal. Figs. 17I-17J. Intercalary arthroconidia of straight, branched fertile hypha. Fig. 17K. Mature arthroconidia with refractile terminal walls. Fig. 17L. Orange brown slime surrounding vegetative hyphae. Colonies x 1.0, others x 830.


C
D
E
G
J

3785, salty soil, France, by J. Villoutreix, from CBS as 361.69

Malbranchea fulva Sigler et Carmichael sp. nov.

Description

Colonies on PYE (Fig. 17G) growing moderately quickly (38-44 mm in 21 days) are slightly raised with central tan or yellow umbo and four or five outer zones varying in color from tan or pale brown to yellow, and at the periphery white or hyaline, reverse dark tan or reddish brown. The zonate pattern is more distinct on half of the colony and the umbo may be situated slightly off center. The texture is powdery though the central umbo may be downy. A tan pigment diffuses slightly into the medium by 21 days.

On cereal agar (Fig. 17H) growth is as rapid (38-42 mm in 21 days) but flat with a small ridge surrounding a zone of less dense aerial growth at the center. The colony is tan or buff brown, reverse tan, powdery or granular. By 21 days, a slight amount of tan or brown pigment appears below the colony.

The maximum temperature for growth is close to 37 C, with some strains growing slightly (2-8 mm in 21 days) and others not at all. The optimum range is 25-30 C.

Hyphae bearing arthroconidia are straight, branched

(Figs. 17I,17J) septate 2-4um wide. Racket hyphae appear during early growth swelling to 5-6um in diameter. Septae formed in the fertile hyphae are thick (Figs. 17I,17J) suggesting double septae, and at maturity arthroconidia develop refractile terminal end walls (Fig. 17K). Arthroconidia are cylindrical or barrel shaped, hyaline, pale yellow, in mass yellow, smooth, 2-3(3.5)um x 3.5-8(11)um, sometimes remaining connected in 2's. Orange brown slime, occurring infrequently, surrounds some hyphae (Fig. 17L).

No other spore state was observed and an attempt to cross the isolates was unsuccessful.

Holotype: air sample, Dugway, Utah, by G.F. Orr, 1967, UAMH 2851 (DPG-167, 0-3042, NRRL 5160)

Discussion

M. *fulva* differs from the *M*. state of *Uncinocarpus reesii* in its slower growing tan colonies and restricted growth at 37 C. *M*. *fulva* lacks the arcuate fertile hyphae of *M*. *arcuata*.

Habitat and Activities

This species has been recovered from air (Orr and Kuehn, 1972), soil and dung, California, Utah and Colorado.

M. *fulva* is strongly keratinolytic, producing marked digestion of hairs with some penetration of the hair by single hyphae. Cellophane is not attacked.

Material Examined

From soil: UAMH 1050, Riverside Co., California, by G.F. Orr, as 0-759; UAMH 1708, Palo Verde, California, by G.F. Orr, 1957, as 0-630; From air sample: UAMH 2849, wind tunnel contaminant, Utah, by G.F. Orr, 1967, as 4TL3; UAMH 2851, TYPE, Dugway, Utah, by G.F. Orr, 1967, as DPG-167 (0-3042, NRRL 5160); From dung: UAMH 3889, mouse, Fruita, Colorado, from Orr as 0-1508; UAMH 3901, lizard, Palo Verde, California, from Orr as 0-1319; From other sources: UAMH 3729, unknown, from Orr as DPG-45.

Malbranchea gypsea Sigler et Carmichael sp. nov.

Description

Colonies on PYE vary somewhat in growth rate, reaching a diameter of 17-39 mm in 21 days, but mostly 27-30 mm. Colonies (Fig. 18A) are chalky white or creamy white, reverse buff, downy or velvety, slightly raised, dome shaped with the surface deeply folded or convoluted, sometimes with prominent central umbo. The colony (Fig. 18B) of two strains (UAMH 1842 and 1843) was smoother with a hairy or coarsely woolly matted texture and glabrous margin.

On cereal, colonies (Fig. 18C) are slow growing (15-42 mm in 21 days, but mostly 27-32 mm) and appear white, reverse white or tan, powdery, downy, or floccose, almost flat or domed with small central umbo and small irregular folds. Tan pigment appeared below the colony of a single strain (UAMH 1975) by 21 days.

Most strains failed to grow at 37 C except UAMH 1841 and 1843 which showed scant growth. One strain (UAMH 1734) grew poorly at 30 C. The optimum temperature is 25-30 C.

Arthroconidia (Figs. 18D,18F), borne in an intercalary or terminal position on the straight primary hyphae or on short or long lateral branches, are separated by one or more alternate empty cells, or rarely, formed immediately adjacent to each other (Fig. 18E). Arthroconidia are cylindrical or slightly barrel shaped with the diameter slightly broader than the diameter of the interconnecting hypha (Figs. 18E,18F), hyaline, smooth, 2-2.5um x (2.5) 3-6 (9) um.

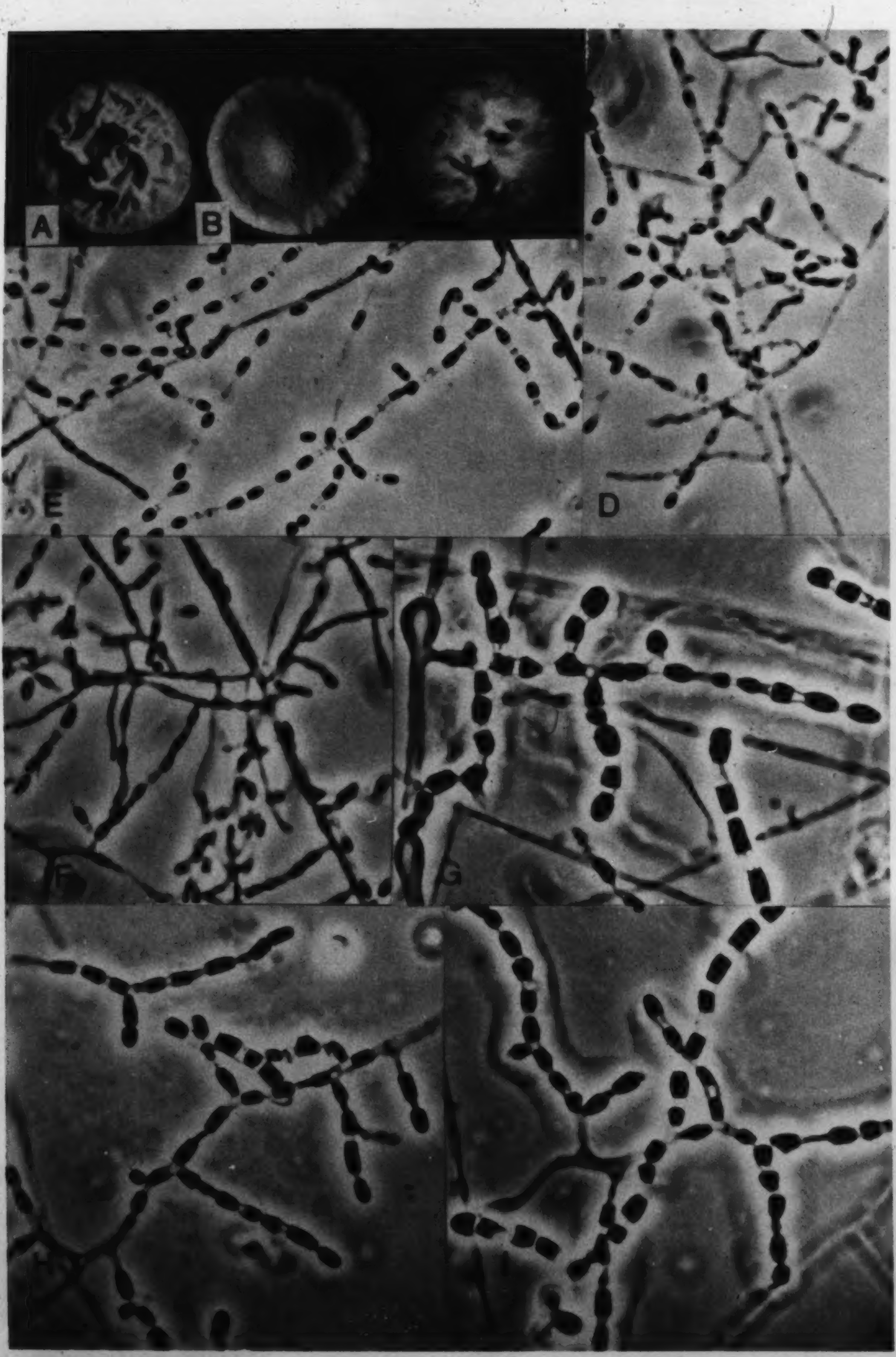
No other spore state was observed. An attempt to cross three isolates (UAMH 1841, 1843 and 1975) with each other was unsuccessful.

Holotype: soil, Bakersfield, California, by G.F. Orr, 1964,
UAMH 1975 (VJC 4, 0-2565)

Discussion

The white colored colonies and lack of arcuate fertile

Figure 18. A-F. Malbranchea gypsea (A,C-UAMH 1975; B-1843; D-F-1841). G-I. Malbranchea state of Coccidioides immitis (3624). Figs. 18A-18C. Colonial morphology after 21 days at 25 C. A and B on PYE, C on cereal. Figs. 18D-18F. Arthroconidia borne on primary hyphae and straight lateral branches. Figs. 18G-18I. Closely spaced, barrel shaped arthroconidia borne on straight lateral branches. Colonies x 1.0, others x 830.


A
B
D
E
F
G
H

hyphae distinguish M. gypsea from most other species of Malbranchea. During early development, M. gypsea may be confused with the Malbranchea state of Uncinocarpus reesii, especially if the characteristic uncinate appendages of the latter are lacking. However, the M. state of U. reesii differs in forming arthroconidia which are slightly broader, 2.5-3um in diameter compared to 2-2.5um for M. gypsea; in growing more vigorously at both 25 C and 37 C; and in being markedly keratinolytic in contrast to M. gypsea which is cellulolytic.

Habitat and Activities

Isolated from soil and cat hair, and recovered from lesions on the spleen and liver after passage through experimental animals, Utah and California (Orr, 1972).

M. gypsea is cellulolytic, weakening the cellophane membrane after prolonged growth. Keratin is not attacked.

Material Examined

Isolates from soil passaged through experimental animals: UAMH 1841, California, from Orr as SFVH 129 (0-3226); UAMH 1842, California, from Orr as SFVH 130 (0-3283); UAMH 1843, California, from Orr as SFVH 149 (?0-1088); From other substrates: UAMH 1734, cat hair, by C.W. Emmons, from Orr as 'cat hair PBSF'; UAMH 1975, TYPE, soil, Bakersfield, California, by G.F. Orr, 1964 as VJC 4 (0-2565)

Malbranchea state of Coccidioides immitis Stiles in Rixford and Gilchrist 1896, Johns Hopkins Hospital Report 1:209-269

Description

The cultural morphology and pathology of *C. immitis* are described in medical mycology textbooks (see Rippon, 1974). Since central Alberta is not an endemic zone, the following description is based on two locally isolated strains (UAMH 3624 and 3667) from infected travellers. Slide cultures of these strains were kindly supplied by Dr. A. S. Sekhon (Provincial Laboratory of Public Health, Edmonton).

The arthroconidia are borne in an intercalary or terminal position on short or long, straight, lateral branches, arising at right angles from the vegetative hypha (Fig. 18G). The vegetative hyphae are narrower than the fertile branches, septate, hyaline, 2-4.5um in diameter, often with enlargements at the septae to 9um in diameter, and do not divide into arthroconidia. Arthroconidia (Figs. 18H,18I) are closely spaced, separated by short segments, hyaline, barrel shaped, cuneiform if terminal, 3-5(6)um x 3-8um, mostly 3.5-4.5um x 3-8um. The diameter of the arthroconidia is the same as the width of the fertile hypha, or only slightly larger.

Discussion

In its arthroconidium formation, *C. immitis* is close to the borderline between *Malbranchea* (conidia mostly less than 4um in diameter) and *Sporendonema* (conidia mostly more than 4um in diameter). However, the general appearance of the fertile hyphae and arthroconidia most closely resembles the other species of *Malbranchea*. Indeed, Huppert *et al*. (1967) apparently confused some isolates of other *Malbranchea* species with *C. immitis* and described them as variants of *C. immitis*. They reported that these unusual isolates produced coccidioidomycosis in mice, but made no mention of controls to rule out the possibility of accidental infection of their mice with *C. immitis*. Their figure 6 displays the distinctive arthroconidial morphology of *Malbranchea dendritica*. The type strain of *M. dendritica* (UAMH 2731) studied by Orr (1972) survived for long periods in mice and could be recovered from the spleen, liver and lung. However, no endosporulating spherules or other fungal elements were found in any tissue.

In the same study, Orr (1972) included three other arthroaleuriospore forming isolates (UAMH 1841, SFVH 129; UAMH 1842, SFVH 130; UAMH 1843, SFVH 149), none of which produced coccidioidomycosis in mice. These three strains, which have been included in the species *Malbranchea gypsea*, are not so distinctive in their microscopic morphology. However, Figure 7 of Huppert *et al*. (1967) suggests *M*.

gypsea and may be a photomicrograph of one of the above strains having SFVH numbers.

Three isolates were received from the CDC as C. immitis from Russia (UAMH 3595, 40-73-48553; UAMH 3596, 40-73-48555; UAMH 3602, 40-73-48554). They form chains of budding conidia and have been assigned to the form-genus Fusidium (Lechevalier, Lechevalier, Handley, Ghosh and Carmichael, 1975).

The arthroconidia of the Malbranchea state of C. immitis are broader than all other species of Malbranchea which are mostly less than 4um in diameter. Arthroconidia of M. sulfurea measure 2.5-4um but this species is thermophilic and forms arcuate fertile hyphae. The arthroconidia of the M. state of U. reesii are slightly narrower, 2.5-3.5um occasionally 4um in diameter and are separated by intervals of irregular length. In addition, the M. state of U. reesii regularly forms uncinate appendages in culture.

Malbranchea state of Uncinocarpus reesii

Sigler et Orr sp. nov.

Perfect State:

Uncinocarpus Sigler et Orr gen. nov.

Diagnosis

Ascocarps more or less spherical, reddish brown. Ascomatal initials on short stalks, bulbous. Peridial hyphae, smooth, aseptate, consisting of elongate appendages loosely intertwined. Free ends extending beyond the core of the ascocarp, uncinate, sometimes spiral. Asci subglobose, evanescent, 8-spored. Ascospores oblate, smooth, yellow to reddish brown. *Malbranchea* conidial state.

Type species: *Uncinocarpus* *reesii* Sigler et Orr sp. nov.

History

This fungus has been frequently isolated during surveys of soil and keratinous substrates. The imperfect state, most often encountered, has been ascribed to *Chrysosporium*, *Malbranchea* or various imperfect forms of Gymnoascaceae. The perfect state has been reported by various workers as a probable new genus of the Gymnoascaceae, but not yet described (see below).

Considerable attention has focused on the imperfect state because of its resemblance to the pathogenic *Coccidioides* *immitis*. Emmons (1954) studied several Gymnoascaceae isolated from organs of rodents and other animals. Some of these, which he called *Myxotrichum* formed the perfect state, whereas others, seemingly degenerate, produced only peridial appendages. This loss of fertility Emmons noted, was related to a change in colony color from orange to white.

Examining two of Emmons' ascosporic isolates, Kuehn (1955a) described *Myxotrichum emmonsii*, later reduced to synonymy with *Auxarthron umbrinum* (Boudier) by Orr and Plunkett (in Orr *et al*., 1963a). Both Kuehn, and Orr and Plunkett described an arthroconidial state, though neither reported the persistence of peridial appendages in degenerate strains.

However, Kuehn *et al*. (1964) discovered several occurrences of appendages in isolates similar to *Auxarthron brunneum*. In a later report, Emmons (1967) confirmed that his isolates earlier designated *Myxotrichum* were *M. emmonsii* Kuehn and again reiterated his observations of peridial appendages persisting in infertile strains. Emmons discerned little difference between *Auxarthron umbrinum* and *A. brunneum* and noted arthroconidia of both resembled *Coccidioides immitis*. Furthermore, Emmons found no evidence to suggest that appendages persisted in any other Gymnoascaceae maintained in culture.

Rees (1967a), surveying keratinophilic fungi from Australia isolated the imperfect state of ? *Gymnoascus uncinatus* from *Rattus rattus*. In a subsequent study Rees (1967b) listed Genus A and noted its similarity to the previously isolated ? *G. uncinatus* which formed only arthroconidia and trichomes in culture. He concluded the relationship of Genus A and the earlier reported ? *G.*

uncinatus to Gymnoascus uncinatus appeared doubtful. Two of Rees' isolates (F143, UAMH 2845 and F122, UAMH 3484) called Genus A, studied by us, presented the first indication that the perfect state of the arthrosporic fungus forming appendages was not in fact Auxarthron as suggested by Emmons.

De Vroey (1970) reported the perfect state as a new genus of Gymnoascaceae from soil in Sulawesi (Celebes Islands). Caretta and Piontelli (1975) discovered an unidentified Gymnoascaceae and its imperfect Chrysosporium stage from woods in Italy.

Hubalek (1974a) reported several isolates of the imperfect state as a probable new species of Auxarthron from birds in Yugoslavia and Czechoslovakia.

Description

Colonies on PYE (Fig. 19A) growing moderately rapidly (51-64 mm in 21 days) are creamy white or buff, never orange, reverse dirty yellow, domed and convoluted, or flatter with outward radiating folds, sometimes umbonate, downy or powdery. If powdery, cracks often appear near the center and along the folds.

At 37 C, colonies grow slowly (6-24 mm at 21 days), adhering poorly to the cellophane becoming heaped up and convoluted, downy, waxy or glabrous, or growing more rapidly

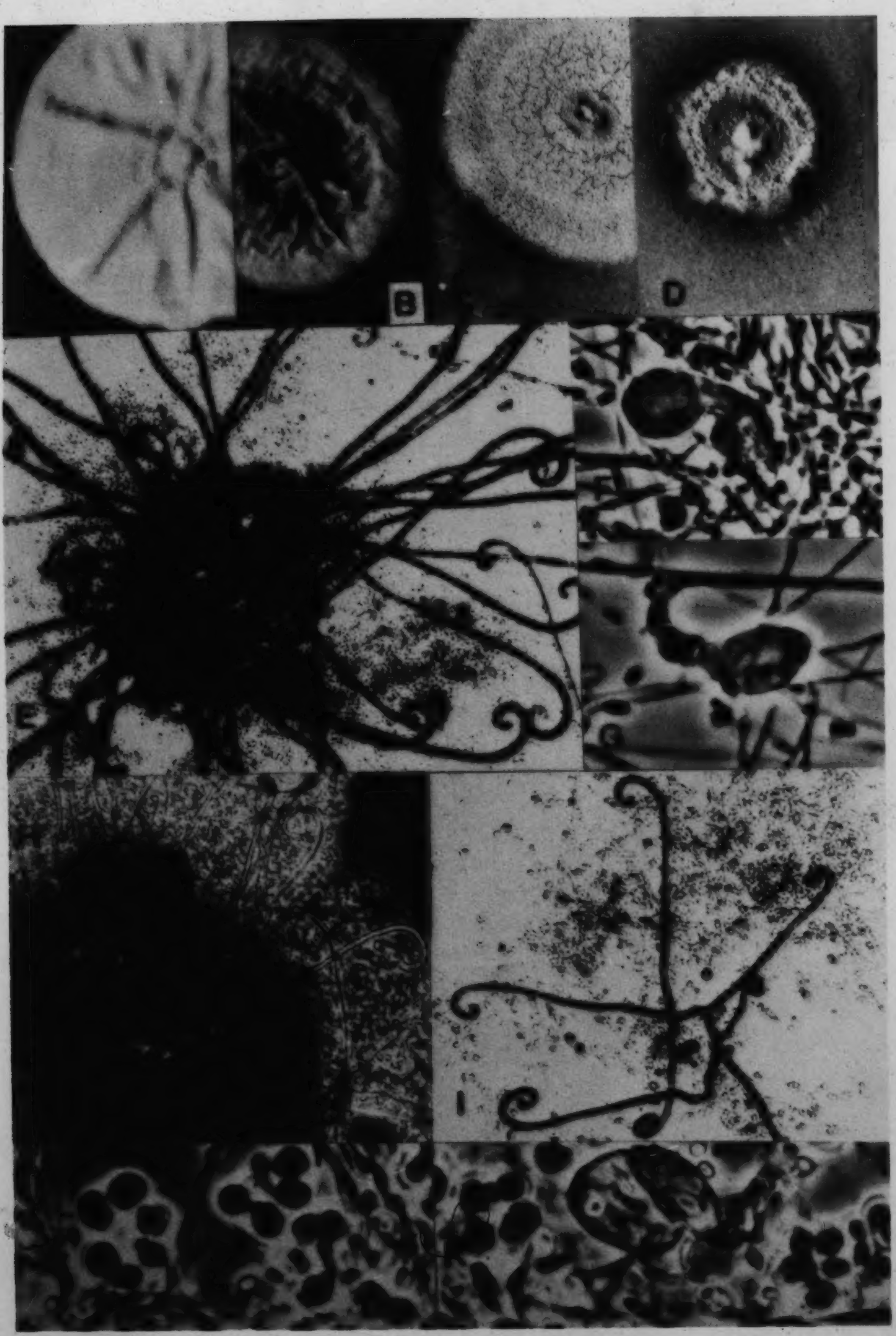
(Fig. 19B) (28-46 mm at 21 days) slightly raised, with numerous folds, white or tan, downy. Dark brown exudate droplets appear on the surface and a yellow pigment diffuses into the medium. This pigment can be detected with difficulty in some strains at 25 C, but is mostly obscured by the yellow color of the PYE.

Colonies on cereal (Fig. 19C) growing moderately rapidly (39-53 mm in 21 days) are creamy white, buff or tan, never orange, with white periphery, reverse the same. The texture is powdery or ganular, rarely downy, dense or patchy appearing mottled, occasionally zonate, flat with small central umbo and numerous tiny cracks or fissures on the surface.

At 37 C, growth at 21 days is scant (5-10 mm) or restricted (14-26 mm). Colonies of the latter (Fig. 19D) are downy, floccose and white, or tan and granular, with a brown pigment diffusing into the medium below (Fig. 19D). This brown pigment is rarely observed at 25 C.

Heterothallic. Cleistothecia (Figs. 19E,19H) are discrete, reddish brown, globose, compacted in the center, 200-1000um, with appendages extending beyond 100-250um. Ascomatal initials, hyaline, arising as short branches, septate at first, with a bulbous enlarged tip, often completely inrolled (Figs. 19F,19G). Cleistothecium composed of a loose association of intertwined appendages, uncinate at each end, often forming one or more lateral

Figure 19. Uncinocarpus reesii (A-D-2847; E-2002x2847; F-3484; G-3573; H-2845; I-2855x3257; J,K-3881x2002). Figs. 19A-19D. Colonial morphology after 21 days, x 1.0. A and B on PYE, C and D on cereal. B and D at 37 C, others at 25 C. Fig. 19E. Fertile cleistothecium composed of loose association of uncinate appendages. x 210 BF. Figs. 19F-19G. Ascomatal initials, x 830. Fig. 19H. Cleistothecium, x 210. Fig. 19I. Intertwined branched uncinate appendages from a fertile cleistothecium, x 210 BF. Fig. 19J. Asci, x 830. Fig. 19K. Asci and ascomatal initial, x 830.

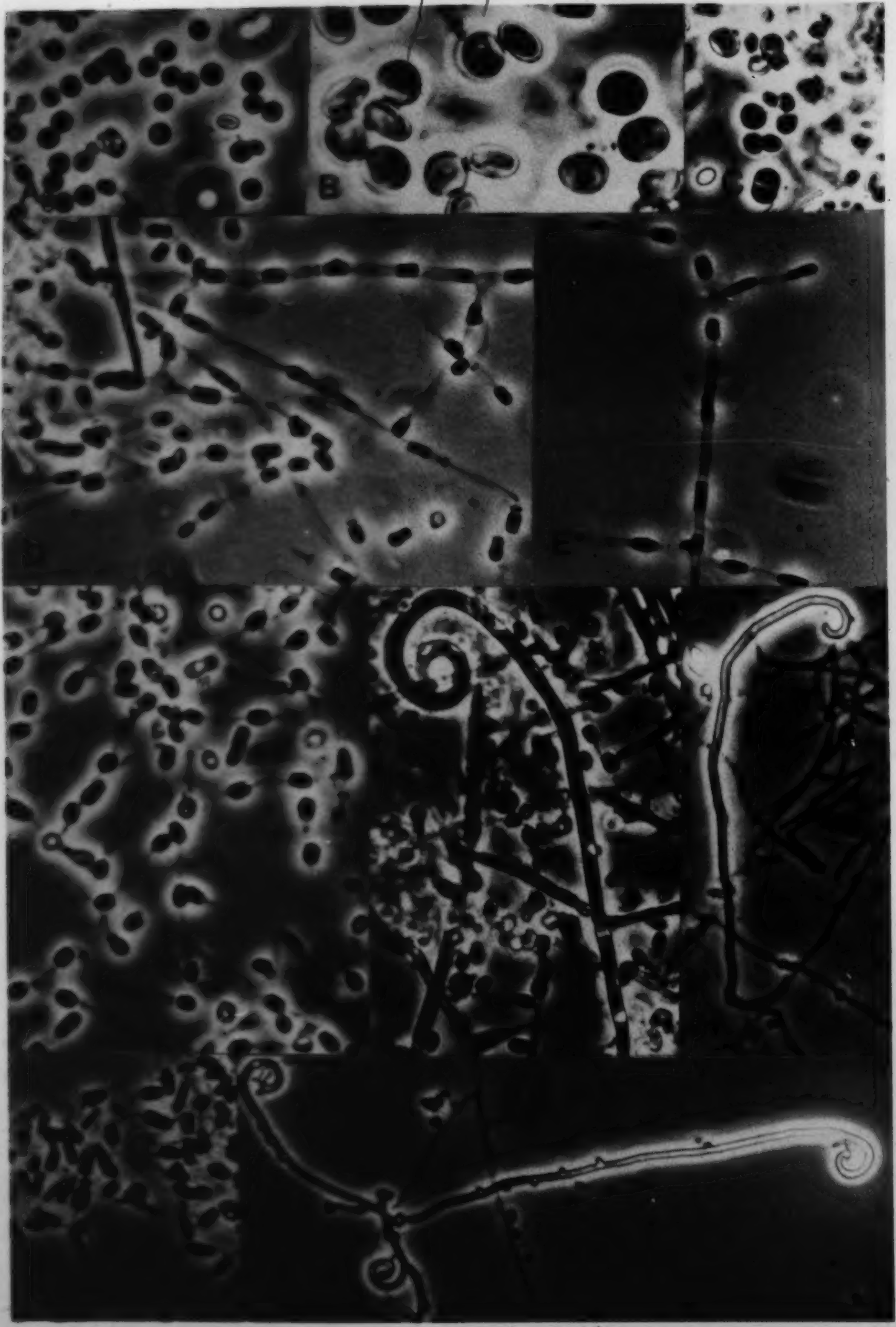

B
D
E
I

uncinate branches (Fig. 19I), smooth, thick walled, aseptate, reddish brown in color. The appendages are mostly uncinate, but occasionally spiral, wide at the tip, 5-8um, narrowing toward the center. No differentiated peridial hyphae are formed, though immature cleistothecia are often surrounded by a loose weft of hyaline hyphae bearing arthroconidia. Asci are evanescent, hyaline, arising on short stalks, subglobose, 7-9um in diameter (Figs. 19J,19K), 8-spored. Ascospores are yellow brown, reddish brown in mass, smooth, oblate, sometimes with a depression in one face (Figs. 20A,20B), 2.5-3um x 4-5um, mostly 2.5-2.8um x 4-4.5um.

Arthroconidia (Figs. 20D,20E), borne in an intercalary position along the broader (2-5um) primary hyphae, or intercalarly or terminally on short or long lateral branches, are cylindrical, sometimes barrel shaped or cuneiform if terminal (Figs. 20F,20I). Separated by one or more segments of irregular length, arthroconidia are hyaline, later tan, smooth, 2-4um x 3-6(8)um, mostly 2.5-3.5um x 3.5-6um. Enlarged subglobose or broadly barrel shaped arthroconidia (Fig. 20C) are found in old cultures and in the vicinity of fertile cleistothecia. They are 5-8um in diameter, hyaline, mostly single celled. Racket hyphae may be present.

Uncinate appendages (Fig. 20G) are characteristic of the imperfect state, appearing in culture after 7-14 days.

Figure 20. Uncinocarpus reesii (A-C-1704x2050; D-2845; E-2991; F-3257; G-1704; H-3485; I-3703; J-2847). Figs. 20A-20B. Smooth oblate ascospores with a depression in one face. Fig. 20C. Ascospores and enlarged, 0 or 1 septate arthroconidia. Figs. 20D-20F. Arthroconidia borne on the primary hyphae or on straight lateral branches. Fig. 20G. Uncinate appendage of the Malbranchea state. Fig. 20H. Uncinate appendage arising as a thick walled extension from the vegetative hypha. Fig. 20I. Mature arthroconidia. Fig. 20J. Branched uncinate appendage of the Malbranchea state. B x 2300, H and J x 330, others x 830.


B
D
E

The appendage, arising mostly as a thick walled, more dense extension from the primary hypha (Fig. 20H) or from a thick walled segment of the hypha resembling a foot cell, becomes uncinate at each end, often forming one or more lateral branches (Fig. 20J). The hypha bearing appendages continues to extend forming arthroconidia along its length. The appendages are mostly uncinate, occasionally spiral, aseptate, pale brown, in color, usually paler in color and slightly narrower in diameter at the tip (3-5um) than the appendages forming the cleistothecium.

Holotype: dried colonies of cross of single ascospore
isolates UAMH 3880x3881, UAMH 3882

Mating types: UAMH 3880 '-', single ascospore isolate 'A' of
UAMH 2845
UAMH 3881 '+', single ascospore isolate 'E' of UAMH 2845

Discussion

Formation of cleistothecia in culture has been observed in two strains, UAMH 2845 and 3484. Single ascospore isolates of both were self-sterile, however (see results of mating tests).

The *Malbranchea* state of *Uncinocarpus reesii* is easily identified by its uncinate appendages. These appendages are lacking in all other *Malbranchea* species and have not been observed in any other conidial state of Gymnoascaceae examined by us. Some strains lack appendages (UAMH 3257 and 3258), but nevertheless can be recognized by their arthroconidia and white or buff colonies.

M. arcuata differs in forming arcuate fertile hyphae. *M. fulva* grows more slowly at both 25 C and 37 C and its arthroconidia are slightly narrower and often refractile at the terminal ends. In addition, the arthroconidia of *M. fulva* are separated by relatively short segments, equivalent to or less than the length of an arthroconidium whereas the intervals between arthroconidia in *U. reesii* are longer and more irregular.

The genera of Gymnoascaceae are differentiated by the peridial hyphae, the shape and surface ornamentation of the ascospores and the ascomatal initials (Samson, 1972). On this basis, *Uncinocarpus* is most closely related to *Gymnoascus* Baranetzky, which also has oblate smooth ascospores. *Gymnoascus*, however, is differentiated by the net-like structure of its peridial hyphae which sometimes terminate in uncinate or elongate appendages, by its ascomatal initials which are coiled, and by its *Chrysosporium* conidial state (Orr *et al*., 1963c; Samson, 1972). The peridial hyphae and reticulate or spiny, globose or oblate ascospores distinguish the genus *Auxarthron*. *Auxarthron* however, is related to *Uncinocarpus* in its keratinolytic activity, its formation of elongate uncinate appendages, and its *Malbranchea* conidial states.

Petalosporus (Ghosh, Orr and Kuehn, 1963) and Shanorella (Benjamin, 1956), two closely related genera, also form oblate ascospores, but differ from Uncinocarpus in their rudimentary peridial hyphae and coiled ascomatal initials. In addition, species of both genera are cellulolytic.

Furthermore, although heterothallic species are common in Nannizzia, Arthroderma and Ctenomyces, none have been reported so far in the other genera of Gymnoascaceae. However, there are several reports of loss of fertility in some species (Orr et al., 1963b; Apinis, 1964; von Arx, 1971; Samson, 1972). The Myxotrichum states of Malbranchea flavoroseus and M. circinata reported herein lacked ascospores, suggesting possible heterothallism.

Results of Mating Tests

A. Notes on techniques

The presence of fertile cleistothecia in two isolates of ? Gymnoascus species, associated with a Malbranchea conidial state, prompted initial investigation of compatibility among several similar Malbranchea strains. Fertile crosses confirmed the perfect state to be Uncinocarpus reesii.

Two methods of inoculation were first tested, the premixed conidial suspension (method A) and the streak-plate method (method C). Method A, similar to that proposed by Padhye _et al_. (1973) had two disadvantages. If a large number of strains were to be tested, it was extremely time consuming, and the possiblity of error increased, either in labelling of the large number of tubes, or in transferring. However, the results of fertile crosses were similar in both methods (Table V) varying slightly in the number of cleistothecia formed. A single exception was the cross of UAMH 3703 x 2002 which failed to develop cleistothecia by method A.

Because of the disadvantages of method A subsequent studies utilized primarily method C and sometimes B, a more simple procedure for mixed suspensions (Table V).

The streak-plate method (C) overall had several advantages. Cleistothecia formed most commonly in the central region between the two strains. This easily found location with less dense vegetative growth increases the ease of observation. Cleistothecia were never formed in great abundance and when small were difficult to differentiate from clumps of conidia. Further, if strains were in fact inhibitory, a readily apparent demarcation zone could be observed between the tester strains. One of the problems associated with sexual crosses is the formation of profuse pleomorphic overgrowth which obscures cleistothecia. This degeneration occurred less rapidly in the streak-plate cultures.

B. Results of crosses

The compatibility among isolates of the Malbranchea state of U. reesii is summarized in Table VI. Of the 19 wild type isolates tested, six were found to be incompatible with all other strains and with each other. The incompatible strains, UAMH 160, 1273, 1706, 1955, 2992 and 3573, resembled the others in microscopic morphology although UAMH 3573 also formed ascomatal initials in abundance. All wild type isolates were self-sterile.

C. F1 progeny

Single ascospore isolates of Uncinocarpus reesii required 30-32 hours at 30 C and up to 48 hours at 25 C before germination occurred.

Two single ascospore progeny of the self-fertile UAMH 2845, determined to be opposite mating types by back crossing with each other, were designated + (UAMH 3881) and - (UAMH 3880) mating types. All F1 progeny were self-sterile. These tester strains when back crossed with four wild conidial isolates known to be fertile, resulted in two fertile crosses, UAMH 2002 x 3881 and UAMH 2847 x 3880 (Table VI). UAMH 2854 and 3485 failed to cross with either mating type (Table VI).

TABLE V
COMPARISON OF ASCOCARP PRODUCTION IN UNCINOCARPUS REESII BY THREE METHODS OF INOCULATION

Minus Strains	2002			2050			3485		
Plus Strains	A	B	C	A	B	C	A	B	C
1704		+++	+++						
2847	+++		+++		+++	+++	+++		+++
2854	+++		++				+		++
2855		++	++						
2991	++	+							
3703	-	++							

Legend:
+ < 10 cleistothecia
++ 10-20 cleistothecia
+++ > 20 cleistothecia
- no fertile cleistothecia
blank: comparative tests not done

A Premixed suspension
B Suspensions mixed on plate
C Separate parallel streaks

TABLE VI
SUMMARY OF THE FERTILE CROSSES OF UNCINOCARPUS REESII

	+ Plus mating strains						
- Minus Strains	1704	2847	2854	2855	2991	3703	3881
2002	+++	+++	+++	++	++	+++	+++
2050	++	+++	-	+++	-	-	N
2852	+	-	-	+++	-	-	N
2862	-	-	-	++	-	-	N
3257	-	-	-	+++	-	-	N
3258	+	-	-	+++	-	-	N
3485	+	+++	++	+	-	-	-
3880	N	+++	-	N	N	N	+++

+ < 10 cleistothecia
++ 10-20 cleistothecia
+++ > 20 cleistothecia
N Not tested

Six wild type isolates incompatible with all other conidial isolates failed to cross with either of these two tester strains. In addition, two F1 progeny from the cross of UAMH 2002 x 2847, found to be + (UAMH 3915) and - (UAMH 3916) mating types by back crossing with the parent strains, were also incompatible with all six wild type isolates.

Increased fertility of mating strains from the progeny of fertile crosses has been reported for other Gymnoascaceae (Kwon-Chung, 1971, 1972; Padhye and Carmichael, 1971, 1973). More work is required to determine if the failure of the six wild type isolates to cross is due to incompatibility or whether the *Malbranchea* state is a complex similar to that of *Microsporum gypseum* (Stockdale, 1963) or *Trichophyton terrestre* (Padhye and Carmichael, 1973).

Pathogenicity

Though the pathogenicity of *U. reesii* has not been firmly established, it appears to be a transient inhabitant of man and animals, and can survive for extended periods in the tissue. Emmons (1954) recovered the organism from organs of rodents and other animals and from small omental abscesses at the site of intraperitoneal inoculation into mice.

Species of *Malbranchea* resembling *C. immitis* in appearance have been recovered from animal tissues, human sources and the spleen and liver of mice after intraperitoneal inoculation (Kuehn et al., 1964; Emmons, 1967; Orr, 1968, 1970). Orr (1972) reported that species of Malbranchea could be recovered from tissues of mice even when no gross lesions were apparent, and that fungal elements were not observed in any lesion.

Habitat and Activities

U. reesii has been recorded from soil of desert and wooded areas, bat guano, keratinous substates such as feathers of wild birds and domestic fowl, organs of rodents and human sources. It appears to have a worldwide distribution.

This species attacks hair vigorously, digesting it with the aid of penetrating bodies. Cellophane is not attacked.

Material Examined

Single ascospores isolates, Alberta, 1975: UAMH 3882, TYPE, dried colonies of cross of UAMH 3880 x 3881; UAMH 3880, - mating type, single ascospore isolate 'A' of UAMH 2845; UAMH 3881, + mating type, single ascospore isolate 'E' of UAMH 2845; UAMH 3883, - mating type, single ascospore isolate 'B' of UAMH 2845; UAMH 3884, - mating type, single ascospore isolate 'C' of UAMH 2845; UAMH 3915, + mating type, single ascospore isolate 'E' of cross of UAMH 2002 x 2847; UAMH 3916, - mating type, single ascospore isolate 'A' of cross of UAMH 2002 x 2847; From keratinous material (self-fertile isolates): UAMH 2845, feathers, Australia, by Rees (F143), 1967, from Orr as 0-3406 (NRRL A-14871, QM 9335); UAMH 3484, feathers, Australia, by Rees (F122), from Orr as 0-3144 (NRRL A-14870); From keratinous material: UAMH 2862, feathers, Australia, by Rees (F122), ?1965, from Orr as F122; UAMH 3485, feathers, Australia, from Orr as 0-3047; UAMH 3843, feathers of *Corvus monedula*, Krivogastani, Yugoslavia, by Hubalek, 1968, as 193D (0-1296); UAMH 3846, nest of *Carduelis cannabina*, Valtice, Czechoslovakia, by Hubalek, 1970, as 539A (0-1304); 0-3367, feather of Jackdaw, Yugoslavia, by Hubalek, (766A), from Orr; From rodent lung: UAMH 160, *Sylvilagus auduboni*, Texas, by C.E. Emmons, 1949 as C 3716; From unknown sources: UAMH 2991, from R.S. Pore, W. Virginia Medical Center, Morgantown as 707; UAMH 2992, from R.S. Pore as 718; From human sources: 0-2559, sputum, Missouri, by Bransberg (118), from Orr; 0-3222, child's hair, Argentina by Negroni (274), from Orr; 0-3718, child's hair, Argentina by Negroni (276), from Orr; 0-782, child's hair, Argentina by Negroni(255), from Orr; From soil, California isolates: UAMH 1704, by Orr 1960, as 0-2080; UAMH 1706, by Orr, 1957, as 0-482a; 0-216, by Orr; 0-2569, by Orr; Hungarian isolates: UAMH 2847, fabric bait, by Orr, 1967 as 0-3513; UAMH 2854, fabric bait, by Orr, 1967, as SZ 284; UAMH 2855, fabric bait, by Orr, 1967 as SZ 303; Italian isolates: UAMH 2002, by Varsavsky, 1964, from Orr, EV 1-14; UAMH 2050, from Varsavsky as I-79; UAMH 2852, by Varsavsky, 1964, from Orr as I26; UAMH 3573, by Varsavsky, from Orr as

0-3407; UAMH 3819, by Varsavsky (I5), from Orr as 0-3344; UAMH 3820, by Varsavsky (I15), from Orr as 0-3233; UAMH 3918, Pavia, by Caretta (E 21 +), from Orr as 0-1322; 0-1323, Pavia, by Caretta (E 25), from Orr; 0-1324, Pavia, by Caretta, (E 9 I+), from Orr; South American isolates: UAMH 1955, Argentina, by Varsavsky, from Orr as EV-5U (0-3597); 0-3451, Argentina by Negroni (408), from Orr; UAMH 1273, Venezuela, by Pollak (5770) from L. Ajello, CDC as 45-36-62; 0-2558, Mexico, Plunkett (707), from Orr; Indian isolates: UAMH 3257, from H.C. Gugnani, National Institute of Communicable Diseases, Delhi, as S673; UAMH 3258, from Gugnani as S1038; 0-2081, by Garg (1045), from Orr.

REFERENCES

Ainsworth, G. C. 1973. Introduction and keys to higher taxa. Chpt. 1. In The Fungi Vol. IVA. (Ainsworth et al., eds.) Academic Press, N.Y.

Ajello, L. and A. Padhye. 1974. Keratinophilic fungi of the Galapagos Islands. Mykosen 17(10):239-243.

Apinis, A. E. 1964. Revision of British Gymnoascaceae. Mycol. Papers CMI 96:1-56.

Apinis, A. E. 1970. Concerning Rollandina. Trans. Brit. mycol. Soc. 55(3):499-502.

Arnaud, G. 1952. Mycologie concrete: genera I. Bull. Soc. Mycol. Fr. 68:181-223.

Arnaud, G. 1954. Mycologie concrete: genera II. Bull. Soc. Mycol. Fr. 69:265-306.

Awao, T. and S.-I. Otsuka. 1973. Notes on thermophilic fungi in Japan (2). Trans. mycol. Soc. Japan 14:221-236.

Bainier, M. G. 1907. Mycotheque de l'ecole de pharmacie. X. Sporendonema casei. Bull. Soc. Mycol. Fr. 23:23-25 and pl. vi.

Baldacci, E., R. Ciferri and E. Vaccari. 1939. Revisione sistematica del genre Malbranchea Sacc. Atti Ist. Bot. Critt. Ital. Univ. Pavia ser. 4; 11:75-103.

Barron, G. L. 1961. Studies on species of Oidiodendron, Helicodendron and Stachybotrys from soil. Can. J. Bot. 39:1563-1571.

Barron, G. L. 1962. New species and new records of Oidiodendron. Can. J. Bot. 40:589-607.

Barron, G. L. and C. Booth. 1966. A new species of Arachniotus with an Oidiodendron conidial state. Can. J. Bot. 44:1057-1061.

Benjamin, R. K. 1956. A new genus of the Gymnoascaceae with a review of other genera. El Aliso 3(3):301-328.

Berkeley, M. J. and C. E. Broome. 1850. Notices of British fungi. Ann. Mag. Nat. Hist., Ser. 2, 5:455-466.

Berkeley, M. J. and C. E. Broome. 1873. Notices of British fungi. Ann. Mag. Nat. Hist. Ser. 4, 11:339-349.

Boeck, L. D., M. M. Hoehn, J. E. Westhead, R. K. Wolter,

D. N. Thomas. 1975. New azasteroidal antifungal antibiotics from Geotrichum flavo-brunneum. 1. Discovery and fermentation studies. J. Antibiot. 28(2):95-101.

Bolognesi, G. and G. A. Chiurco. 1925. Sopr una nuova micosi del torace ("Malbranchea Bolognesii-Chiurcoi" Vuillemin, Pollacci et Nannizzi) Arch. Biol. (Genoa) Nuova Ser., 1:255-276.

Bonorden, H. F. 1851. Handbuch der Allgemeinen Mykologie. Stuttgart.

Brefeld, O. 1889. Basidiomyceten III. Untersuchungen aus dem gesanntgebiete der mykologie. VIII. Heft. Verlag von Arthur Felix, Leipzig.

Brodie, H. J. 1936. The occurrence and function of oidia in the Hymenomycetes. Am. J. Bot. 23(5):309-327.

Bubak, F. 1912. Ein beitrag zur pilzflora von sachsen. Ann. Mycol. 10:51-53

Buller, A. H. R. 1933. Researches on Fungi. Vol. 5. Longmans, Green and Co., London.

Butler, E. E. and L. J. Petersen. 1972. Endomyces geotrichum a perfect state of Geotrichum candidum. Mycologia 64(2):365-374.

Calavan, E. C. and J. M. Wallace. 1954. Hendersonula toruloidea Nattrass on citrus in California. Phytopathology 44:635-639.

Campbell, C. K. 1974. Studies on Hendersonula toruloidea isolated from human skin and nail. Sabouraudia 12:150-156.

Campbell, C. K., A. Kurwa, A.-H. M. Abdel-Aziz and C. Hodgson. 1973. Fungal infection of skin and nails by Hendersonula toruloidea. Brit. J. Dermat. 89:45-52.

Caretta, G. 1959. Caratteristiche ed affinita del genere Coprotrichum. Atti Ist. Bot. Critt. Univ. Pavia, ser. 5, 17:2-12.

Caretta, G. 1960. Coremiella cuboidea (Sacc. et Ell.) Cif. et Car. n. comb. isolata da feci umane. Mycopath. et Mycol. Appl. 12(3):233-250.

Caretta, G. and E. Piontelli. 1975. Isolation of keratinophilic fungi from soil in Pavia, Italy. Sabouraudia 13:33-37.

Carmichael, J. W. 1955. Lacto-fuchsin: a new medium for mounting fungi. Mycologia 47(4):611.

Carmichael, J. W. 1957. *Geotrichum candidum*. Mycologia 49(6):820-830.

Carmichael, J. W. 1962. *Chrysosporium* and some other aleuriosporic Hyphomycetes. Can. J. Bot. 40:1137-1173.

Carmichael, J. W. 1963. Dried mold colonies on cellophane. Mycologia 55(3):283-288.

Chang, Y. 1967. The fungi of wheat straw compost. II. Biochemical and physiological studies. Trans. Brit. mycol. Soc. 50(4):667-677.

Chang, Y. and H. J. Hudson. 1967. The fungi of wheat straw compost. I. Ecological studies. Trans. Brit. mycol. Soc. 50(4):649-666.

Chapman, E. S. 1974. Effect of temperature on growth of seven thermophilic fungi. Mycologia 66(3):542-546.

Chidester, M. S. 1940. A pink stain of wood caused by a species of *Geotrichum*. Phytopathology 30:530-536.

Ciferri, R. 1958. Manuale di Micologia Medica. Tomo I. Renzo, Cortino, Pavia 370pp.

Cochet, G. 1939. Sur un nouveau champignon arthrospore (*Arthrographis langeroni*) agent pathogen d'une onychomycose humaine. n. g., n. sp. Ann. Parasit. Hum. Comp. 17:98-101 and pl. 3.

Cole, G. T. and W. B. Kendrick. 1969. Conidium ontogeny in Hyphomycetes. The arthrospores of *Oidiodendron* and *Geotrichum*, and the endoarthrospores of *Sporendonema*. Can. J. Bot. 47:1773-1780.

Cooney, D. G. and R. Emerson. 1964. Thermophilic Fungi. W. H. Freeman and Co., San Francisco. 188 pp.

Corda, A. C. I. 1838. Icones fungorum hucusque cognitorum. Tomus II:1-43.

Crisan, E. V. 1973. Current concepts of thermophilism and the thermophilic fungi. Mycologia 65:1171-1198.

Dale, E. 1903. Observations on Gymnoascaceae. Ann. Bot. 17:571-596.

Davidson, R. W., W. A. Campbell and G. W. Weber. 1942. *Ptychogaster cubensis*, a wood decaying fungus of southern oaks and waxmyrtle. Mycologia 34:142-153.

Davidson, R. W., C. M. Christensen and E. F. Darley. 1946. Polyporus guttulatus and Ptychogaster rubescens. Mycologia 38:652-663.

Davis, W. H. 1939. A bud and twig blight of azalea caused by Sporocybe azaleae. Phytopathology 29:517.

Dawson, C. O. and J. C. Gentles. 1961. The perfect states of Keratinomyces ajelloi Vanbreuseghem, Trichophyton terrestre Durie and Frey and Microsporum nanum Fuentes. Sabouraudia 1:49-57.

Dawson, C. O., J. C. Gentles and E. M. Brown. 1964. Environmental conditions affecting sexual reproduction in Arthroderma and Nannizzia. Sabouraudia 3(3):245-250.

De Lamater, E. D. 1937. Eidamella spinosa Matruchot and Dassonville refound. Mycologia 29:572-582.

Desmazieres, M. J. B. H. J. 1827. Observations sur le Sporendonema casei; nouveau genre de Mucedinees. Ann. Sci. Nat. XI:246-249.

Deverall, B. J. 1968. Psychrophiles In The Fungi vol. III (Chpt. 5) (Ed. Ainsworth, G. C. and A. S. Sussman) Academic Press, N. Y.

De Vroey, C. H. 1970. Contribution a l'etude des dermatophytes et d'autres Gymnoascacees. Ann. Soc. belge Med. trop. 50:1-174.

Dodge, C. W. 1935. Medical Mycology. C. V. Mosby, St. Louis 900 pp.

Donk, M. A. 1933. Revision der niederlanischen Homobasidiomycetae Aphyllophoraceae II, 9. Mededeelingen van het Botanisch Museum en Herbarium van de Rijks Universiteit te Utrecht 22:153.

Eicker, A. 1972. Occurrence and isolation of South African thermophilic fungi. S. Afr. J. Science 68:150-155.

Eidam, E. 1882. Uber entwicklungsgeschicte der ascomyceten botanische. Zentralblat. 10:106-107.

Elisei, F. G. 1940a. Nuovo reperto e nuova interpretazione morfologica e sistematica di Malbranchea pulchella Sacc. et Penz. considerata come una nuova specie e un nuova genere di dermatofiti. Atti Ist. Bot. Critt. Univ. Pavia, Ser. 4; 12:141-200.

Elisei, F. G. 1940b. Le ife pettinate e i fusi di Malbranchea Sacc. Atti Ist. Bot. Critt. Pavia, Ser. 4, 12:213-219.

Ellis, M. B. 1971. Dematiaceous Hyphomycetes. Commonwealth Mycological Institute, Kew, Surrey.

Emmons, C. W. 1954. Isolation of Myxotrichum and Gymnoascus from the lungs of animals. Mycologia 46:334-338.

Emmons, C. W. 1967. Fungi which resemble Coccidioides immitis. In Coccidioidomycosis (Ed. L. Ajello) University of Arizona Press, Tucson.

Eriksson, J. and L. Ryvarden. 1973. The Corticiaceae of North Europe. Vol. 2. Fungiflora, Oslo, Norway.

Evans, H. C. 1971. Thermophilous fungi of coal spoil tips II. Trans. Brit. mycol. Soc. 57(2):255-266.

Fassatiova, O. 1971. Some new records of Hyphomycetes from Czechoslovakia. Cseka Mykologie 25(2):112-117.

Fennell, D. I. 1973. Plectomycetes; Eurotiales. Chpt. 4. In The Fungi Vol. IVA (Ainsworth, G. C., F. K. Sparrow and A. S. Sussman, eds.) Academic Press, N. Y.

Fergus, C. L. 1969. The cellulolytic activity of thermophilic fungi and actinomycetes. Mycologia 61:120-129.

Fidalgo, O. 1958. Studies on Ptychogaster rubescens Boud. the chlamydosporiferous form of Polyporus guttulatus Pk. Mycologia 50:831-836.

Findlay, J. A. and D. Kwan. 1973a. Scytalone (3,6,8-trihydroxytetralone), a metabolite from a Scytalidium species. Can. J. Chem. 51(10):1617-1619.

Findlay, J. A. and D. Kwan. 1973b. Metabolites from a Scytalidium species. Can. J. Chem. 51(19);3299-3301.

Fries, E. M. 1832. Systema Mycologicum 3:434

Gentles, J. C. and E. G. V. Evans. 1970. Infection of the feet and nails with Hendersonula toruloidea. Sabouraudia 8:72-75.

Geigert, J., F. R. Stermitz and H. A. Schroeder. 1973. Two new natural substituted hexenophenones from the fungus Scytalidium. Tetrahedron 29:2343-2345.

Ghosh, G. R., G. F. Orr and H. H. Kuehn. 1963. A new genus of the Gymnoascaceae with a rudimentary peridium. Mycopath. et Mycol. Appl. 21(1):36-44.

Gordee, R. S. and T. F. Butler. 1975. New azasteroidal antifungal antibiotics from Geotrichum flavo-brunneum. III. Biological activity. J. Antibiot. 28(2):112-117.

Gould, W. D., J. I. Fujikawa and F. D. Cook. 1974. A soil fungus tolerant to extreme acidity and high salt concentration. Can. J. Microbiol. 20(7):1023-1027.

Hammer, B. W. and J. C. Gilman. 1944. Red mold on blue cheese. J. Dairy Science 27:413-418.

Hennebert, G. L. 1971. Pleomorphism in fungi imperfecti. In Taxonomy of Fungi Imperfecti (Kendrick, W. B., ed.) Univ. of Toronto Press, Toronto.

Heslop-Harrison, J. 1962. Purposes and procedures in the taxonomic treatment of higher organisms. In Microbial Classification (Ainsworth, G. C. and P. H. A. Sneath, eds.) University of Cambridge Press, Cambridge.

Holubova-Jechova, V. 1969. New species of the genus Oidium Link ex. Fr. emend. Linder. Ceska Mykologie 23(4):209-221.

Hubalek, Z. 1974a. Fungi associated with free-living birds in Czechoslovakia and Yugoslavia. Acta Scientiarum naturalium, Brno 8(3):1-62.

Hubalek, Z. 1974b. The distribution patterns of fungi in free-living birds. Acta Scientiarum naturalium, Brno 8(9):1-51.

Hubalek, Z., F. Balat, I. Touskova and J. Vik. 1973. Mycoflora of birds' nests in nest-boxes. Mycopath. et Mycol. Appl. 49(1):1-12.

Hubalek, A. and F. Balat. 1974. The survival of microfungi in the nests of tree sparrow Passer montanus L. in the nest-boxes over the winter season. Mycopath. et Mycol. Appl. 54:517-530.

Hudson, H. J. 1973. Thermophilous and thermotolerant fungi in the air-spora at Cambridge. Trans. Brit. mycol. Soc. 60(3):596-599.

Hughes, S. J. 1952. Fungi from the gold coast. I. Mycol. Papers CMI 48:40.

Hughes, S. J. 1953. Conidiophores, conidia and classification. Can. J. Bot. 31:577-659.

Hughes, S. J. 1958. Revisiones hyphomycetum aliquot cum appendice de nominibus rejiciendis. Can. J. Bot. 36:727-836.

Hughes, S. J. 1959. Starting point of nomenclature of Hyphomycetes. Taxon 8(3):96-103.

Hughes, S. J. 1968. Some Gymnoascaceae. Can. J. Bot. 46:939-943.

Huppert, M., S. H. Sun and J. W. Bailey. 1967. Natural variability in Coccidioides immitis. In Coccidioidomycosis (Ed. L. Ajello) Univ. Arizona Press, Tucson.

Hussain, A. and M. A. B. Malik. 1972. Three new records of fungi from Pakistan. Pak. J. Sci. Ind. Res. 15:88.

Kambayashi, T. 1934. Uber ein von einer spezies der Malbranchea hervorgerufenes haut leiden in China. Arch. Dermatol. Syph. 170:97-106.

Kendrick, W. B. 1971. Taxonomy of Fungi Imperfecti. Univ. Toronto Press, Toronto.

Kendrick, W. B. and J. W. Carmichael. 1973. Hyphomycetes. Chpt. 10. In The Fungi Vol. IVA. (Ainsworth et al., eds) Academic Press, N. Y.

Kiffer, E., F. Mangenot, and O. Reisinger. 1969. Sur la position taxinomique de quelques Hyphomycetes isoles des sols de la R. C. P. 40. Rev. Ecol. Biol. Sol, 6(2):181-194.

Klingstrom, A. and L. Beyer. 1965. Two new species of Scytalidium with antagonistic properties to Fomes annosus (Fr.) Cke. Svensk Botanisk Tidskrift 59(1):30-36.

Klingstrom, A. E. and S. M. Johansson. 1973. Antagonism of Scytalidium isolates against decay fungi. Phytopathology 63(4):473-479.

Kobayashi, Y., N. Hiaratsuka, R. P. Korf, K. Tubaki, K. Aoshima, M. Soneda, and J. Sugiyama. 1967. Mycological studies of the Alaskan arctic. Ann. Rep. Inst. Ferm. Osaka 3(1):202.

Kobayashi, Y., N. Hiratsuka, Y. Otani, K. Tubaki, S.-I. Udagawa and M. Soneda. 1969. The second report on the mycological flora of the Alaskan arctic. Bull. Nat. Sci. Mus. 12(2):311-430.

Komatsu, M. 1969. Notes on the hyphomycetous fungi isolated from sawdust-ricebean media of *Pholiota nameko* (Ito) Ito et Imai. Rep. Tottori Mycol. Inst. 7:78-89.

Kuehn, H. H. 1955a. Observations on Gymnoascaceae I. *Myxotrichum uncinatum* and a new species of *Myxotrichum*. Mycologia 47:533-545.

Kuehn, H. H. 1955b. Observations of Gymnoascaceae II. Two new species of *Myxotrichum*. Mycologia 47:878-889.

Kuehn, H. H. 1959. A preliminary survey of the Gymnoascaceae II. Mycologia 51:665-692.

Kuehn, H. H. and G. F. Orr. 1959. Observations on Gymnoascaceae VI. A new species of *Arachniotus*. Mycologia 51:864-870.

Kuehn, H. H., G. F. Orr and G. R. Ghosh. 1964. Pathological implications of the Gymnoascaceae. Mycopath. et Mycol. Appl. 24(1):35-46.

Kwon-Chung, K. J. 1971. Genetic analysis on the incompatibility system of *Ajellomyces dermatitidis*. Sabouraudia 9:231-238.

Kwon-Chung, K. J. 1972. Genetic study on the incompatibility system in *Arthroderma simii*. Sabouraudia 10:74-78.

Lechevalier, H., M. P. Lechevalier, D. A. Handley, B. K. Ghosh and J. W. Carmichael. 1976. Strains of fusidia which can be mistaken for actinomycetes. Mycologia (in press).

Lindau, G. 1907. Hyphomyctes (erste halfte). *In* Rabenhorst's Kryptogamen-Flora von Deutschland, Oesterreich und der Schweiz. 2 ed. Vol. 1, Sect. VIII, E. Kummer, Leipzig.

Lindau, G. 1910. Hyphomycetes (zweite halfte). *In* Rabenhorst's Kryptogamen-Flora von Deutschland, Oesterreich und der Schweiz. 2 ed., Vol. 1, Sect. IX, E. Kummer, Leipzig.

Linder, D. H. 1942. A contribution towards a monograph of the genus *Oidium* (Fungi Imperfecti). Lloydia 5:165-207.

Lowry, R. J. and A. S. Sussman. 1966. Intra-hyphal hyphae in "clock" mutants of *Neurospora*. Mycologia 58:541-548.

Lucas, M. T., A. B. Carvalho and M. C. Barreiro. 1974. Pear fruit rot caused by *Coremiella cubispora*.

Trans. Brit. mycol. Soc. **62**:206-208.

Malloch, D. and R. F. Cain. 1971. New genera of Onygenaceae. Can. J. Bot. **49**(6):838-846.

Massee, G. and E. S. Salmon. 1902. Researches on coprophilous fungi. II. Annals Botany, London **16**:57-93.

Maxwell, M. B. 1954. Studies of Canadian Thelephoraceae. XI. Conidium production in the Thelephoraceae. Can. J. Bot. **32**:259-280.

Michel, K. H., R. L. Hamill, S. H. Larsen and R. H. Williams. 1975. New azasteroidal antifungal antibiotics from *Geotrichum flavo-brunneum*. II. Isolation and characterization. J. Antibiot. **28**(2):102-111.

Miehe, H. 1907. *Thermoideum sulfureum* n. g., n. sp., ein neuer warmepilz. Deutsche Botanische Gesellschaft **25**:510-515.

Miller, J. H., J. E. Giddens and A. A. Foster. 1957. A survey of the fungi of forest and cultivated soils of Georgia. Mycologia **49**:779-808.

Minoura, K., M. Yokoe, T. Kizima and T. Nehira. 1973. Thermophilic filamentous fungi in Japan. Trans. mycol. Soc. Japan **14**(4):352-361.

Morrall, R. A. A. 1968. Two new species of *Oidiodendron* from boreal forest soils. Can. J. Bot. **46**:203-206.

Morris, E. F. 1963. The synnematous genera of the Fungi Imperfecti. West. Ill. Univ. Ser. Biol. Sci. **3**:32-33.

Muller, E., J. Harr and P. Sulmont. 1969. Deux Ascomycetes dont le stade conidien presente des conidies phaeophragmiees endogenes. Rev. Mycol. **33**(5):369-378.

Muller, E. and R. Pacha-Aue. 1968. Untersuchungen an drei arten von *Arachniotus* Schroeter. Nova Hedwigia **15**:551-558 and Taf. 76-78.

Mumma, R. O., C. L. Fergus and R. D. Sekura. 1970. The lipids of thermophilic fungi: lipid composition comparisons between thermophilic and mesophilic fungi. Lipids **5**:100-103.

Murao, S., K. Oda and Y. Matsushita. 1973. Isolation and identification of a microorganism which produces non *Streptomyces* pepsin inhibitor and N-diazoacetyl-DLnorleucine methylester senstitive acid proteases. Agr. Biol. Chem. 37:1417-1421.

Nag Raj, T. R. and B. Kendrick. In press. A Monograph of Chalara and Allied Genera. Univ. of Toronto Press, Toronto.

Nattrass, R. M. 1933. A new species of Hendersonula (H. toruloidea) on deciduous trees in Egypt. Tran. Brit. mycol. Soc. 18:189-198.

Nobles, M. K. 1948. Studies in forest pathology. VI. Identification of cultures of wood rotting fungi. Can. J. Research, C, 26:281-431.

Ong, P. S. and G. M. Gaucher. 1973. Protease production by thermophilic fungi. Can. J. Microbiol. 19:129-133.

Orr, G. F. 1968. Some fungi isolated with Coccidioides immitis from soils in endemic areas in California. Bull. Torrey Bot. Club 95(5):424-431.

Orr, G. F. 1970. Neogymnomyces, a new genus of the Gymnoascaceae. Can. J. Bot. 48(6):1061-1066.

Orr, G. F. 1972. Recovery of several arthroaleuriosporous fungi from mice following intraperitoneal inoculation. Mimeographed Technical Report, Desert Test Center, Dugway, DTC project number TN-72-542 (RDTE number I-T-O-61101-A-91A, USATECOM number 9-CO-043-000-002).

Orr, G. F. and H. H. Kuehn. 1963. Gymnoascus verticillatus Smith. Mycopath. et Mycol. Appl. 21(3-4):211-216.

Orr, G. F. and H. H. Kuehn. 1964a. A reevaluation of Myxotrichum spinosum and M. cancellatum. Mycologia 56(4):473-481.

Orr, G. F. and H. H. Kuehn. 1964b. A new genus of the Gymnoascaceae with dark ascocarps. Mycologia 54(4):482-487.

Orr, G. F. and H. H. Kuehn. 1971. Notes on Gymnoascaceae. I. A review of eight species. Mycologia 63(2):191-203.

Orr, G. F. and H. H. Kuehn. 1972. Notes on Gymnoascaceae. II. Some Gymnoascaceae and keratinophilic fungi from Utah. Mycologia 64:55-72.

Orr, G. F., H. H. Kuehn and O. A. Plunkett. 1963a. A new genus of the Gymnoascaceae with swollen peridial hyphae. Can. J. Bot. 41:1439-1456.

Orr, G. F., H. H. Kuehn and O. A. Plunkett. 1963b. The genus *Myxotrichum* Kunze. Can. J. Bot. 41:1457-1480.

Orr, G. F., H. H. Kuehn and O. A. Plunkett. 1963c. The genus *Gymnoascus* Baranetzky. Mycopath. et Mycol. Appl. 21(1):1-18.

Oudemans, C. A. J. A. 1904. *Exosporina Laricis* Oud. A new microscopic fungus occurring on the Larch and very injurious to this tree. Proc. K. Akad. Wetensch. Amersterdam 6:498-501 and fig. A-C.

Paden, J. W. 1975. Ascospore germination, growth in culture, and imperfect spore formation in *Cookeina sulcipes* and *Phillipsia crispata*. Can. J. Bot. 53(1):56-61.

Padhye, A. A. 1969. Behavior of non-pigment forming isolates of *Keratinomyces ajelloi* mated with *Arthroderma uncinatum*. Mycologia 61:1175-1177.

Padhye, A. A. and J. W. Carmichael. 1969. Mating behavior of *Trichophyton mentagrophytes* varieties paired with *Arthroderma benhamiae* mating types. Sabouraudia 7(3):178-181.

Padhye, A. A. and J. W. Carmichael. 1971. Incompatibility in *Microsporum cookei*. Sabouraudia 9:27-29.

Padhye, A. A. and J. W. Carmichael. 1972. *Arthroderma insingulare* sp. nov., another gymnoascaceous state of the *Trichophyton terrestre* complex. Sabouraudia 10:47-51.

Padhye, A. A. and J. W. Carmichael. 1973. Mating reactions in the *Trichophyton terrestre* complex. Sabouraudia 11:64-69.

Padhye, A. A., A. S. Sekhon and J. W. Carmichael. 1973. Ascocarp production by *Nannizzia* and *Arthroderma* on keratinous and non-keratinous media. Sabouraudia 11:109-114.

Plunkett, O. A., L. Walker and M. Huppert. 1963. An unusual isolate of *Coccidioides immitis* from the Los Banos area of California. Sabouraudia 3(1):16-20.

Pouzar, Z. and V. Jechova. 1967. *Botryobasidium robustior* spec. nov., a perfect state of *Oidium rubiginosum* (Fr.) Linder. Ceska Mykologie 21(2):69-73.

Quinta, M. L. 1968. Natural destruction of the mycological flora of sea salt. Food Technology 22(12):103-105.

Rea, C. 1922. British Basidiomycetae. Cambridge Univ. Press

Rebell, G. and D. Taplin. 1970. Dermatophytes. Their Recognition and Identification. U. Miami Press, Coral Gables, Florida.

Redaelli, P. and R. Ciferri. 1934. Studio comparativo di ventum ceppi di *Sporendonema epizoum* (Corda) Nobis (= *Hemispora stellata* Vuillemin; = *Oospora d'Agatae* Saccardo; ecc.). Atti Ist. Bot. Critt. Univ. Pavia, ser. 4, 5:145-198.

Rees, R. G. 1967a. Keratinophilic fungi from Queensland. I. Isolations from animal hair and scales. Sabouraudia 5(3):165-172.

Rees, R. G. 1967b. Keratinophilic fungi from Queensland. III. Isolations from feathers of domestic fowls. Sabouraudia 6(1):19-28.

Ricard, J. L. and W. B. Bollen. 1968. Inhibition of *Poria carbonica* by *Scytalidium* sp., an imperfect fungus from Douglas-fir poles. Can. J. Bot. 46:643-647.

Rippon, J. W. 1974. Medical Mycology. W. B. Saunders and Co., Philadelphia.

Rivelloni, G. 1938. Isolamento di un raro micete (*Malbranchea Bolognesii-Chiurcoi*) da una micosi umana. Boll. Sez. Reg. Suppl. Giorn. Ital. Derm. Sif. 16:384.

Rode, L. J., J. W. Foster and T. V. Schuhardt. 1947. Penicillin production by a thermophilic fungus. J. Bact. 53:565-566.

Saccardo, P. A. 1882. Michelia commentarium mycologicum fungos in primis Italicos 2:638

Saccardo, P. A. 1886. Sylloge fungorum omnium hucusque cognitorum IV: 1-807.

Saccardo, P. A. 1888. Sylloge fungorum omnium hucusque cognitorum 6:388.

Saccardo, P. A. 1908. Notae mycologicae. Ser. X. Ann. Mycol. 6:553-569.

Saccardo, P. A. and A. Trotter. 1913. Sylloge fungorum omnium hucusque cognitorum 22:1240.

Saez, H. 1964. *Geotrichum vanriji* nouvelle espece de champignon arthrospore isole chez une sarcelle d'ete

(*Anas querquedula* L.). Bulletin Mensuel Societe Linneenne Lyon *33*(7):263-267.

Samson, R. A. 1972. Notes on *Pseudogymnoascus*, *Gymnoascus* and related genera. Acta Bot. Neerl. *21*(5):517-527.

Samson, R. A. and H. A. van der Aa. 1973. Het ascomycet engeslacht *Onygena*. Coolia *16*(12):30-35.

Sekhon, A. S., A. A. Padhye and J. W. Carmichael. 1973. Mating reactions in *Arthroderma tuberculatum*. Sabouraudia *11*:283-286.

Shields, J. K. 1969. Microflora of eastern Canadian wood chip piles. Mycologia *61*:1165-1168.

Sigler, L. and J. W. Carmichael. 1974. A new acidophilic *Scytalidium*. Can. J. Microbiol. *20*(2):267-268.

Singh, S., B. Singh, and R. K. Bakshi. 1961. *Merulius tremellosus* (Schrad.) Fr. and its *Ptychogaster* stage. Can. J. Bot. *39*:1845-1847.

Smith, A. L. 1900. Some new microscopic fungi. VII. Journal Royal Microscopic Society *1900*:422-424.

Smith, A. L. 1901. Fungi new to Britain. Trans. Brit. mycol. Soc. *1*:150-158.

Smith, G. 1962. Some new and interesting species of micro-fungi. III. Trans. Brit. mycol. Soc. *45*(3):387-394 and pl. 8, fig. 4.

Smith, R. G. and A. Ofosu-Asiedu. 1972. Distribution of thermophilic and thermotolerant fungi in a spruce-pine chip pile. Can. J. Forest Res. *2*(1):16-26.

Stalpers, J. A. 1975. Revision of the genus *Oedoceophalum* (Fungi Imperfecti). Proc. Koninkl. Nederl. Akad. van Wetenschappen, Amsterdam. Ser. C, *77*(4):383-401.

Starkey, R. L. 1973. Effect of pH on toxicity of copper to *Scytalidum* sp., a copper tolerant fungus, and some other fungi. J. Gen. Microbiol. *78*:217-225.

Starkey, R. L. and S. A. Waksman. 1943. Fungi tolerant to extreme acidity and high concentrations of copper sulfate. J. Bact. *45*(5):509-519.

Stillwell, M. A., R. E. Wall and G. M. Strunz. 1973. Production, isolation, and antifungal activity of scytalidin, a metabolite of *Scytalidium* species. Can. J. Microbiol. *19*(5):597-602.

Stockdale, P. M. 1963. The *Microsporum gypseum* complex (*Nannizzia incurvata* Stockd., *N. gypsea* (Nann.) comb. nov., *N. fulva* sp. nov.). Sabouraudia *3*(1):114-126.

Stolk, A. C. and R. A. Samson. 1972. The genus *Talaromyces*. Studies on *Talaromyces* and related genera II. Studies in Mycology *2*:1-65.

Sumstine, D. R. 1913. Studies on North American hyphomycetes. II. The tribe Oosporeae. Mycologia *5*:45-61.

Sutton, B. C. 1973. Hyphomycetes from Manitoba and Saskatchewan, Canada. Mycol. Papers CMI *132*:1-143.

Szathmary, S. 1967a. Verfahren zur zuchtung krankheitserregender fadenpilze aus verfaulendem stroh und maisstengeln. Mykosen *10*(4):153-162.

Szathmary, S. 1967b. Pseudomakrokonidiumbildung bei der ungarischen variation von *Gymnoascus verticillatus*. Mykosen *10*(7):271-280.

Taber, R. A. and R. E. Pettit. 1975. Occurrence of thermophilic microorganisms in peanuts and peanut soil. Mycologia *67*(1):157-161.

Tansey, M. R. 1970. Experimental studies of thermophilic and thermotolerant fungi, with emphasis on their occurrence in wood chip piles, cellulolytic ability, nutrition and physiology. Ph.D. thesis, unpublished. Univ. California Berkeley.

Tansey, M. R. 1971a. Agar-diffusion assay of cellulolytic ability of thermophilic fungi. Arch. Mikrobiol. *77*:1-11.

Tansey, M. R. 1971b. Isolation of thermophilic fungi from self-heated, industrial wood chip piles. Mycologia *63*:537-547.

Tansey, M. R. 1975. Isolation of thermophilic fungi from snuff. Appl. Microbiol. *29*(1):128-129.

Tewari, R. P. and C. R. Macpherson. 1968a. Cross-protection between *Histoplasma capsulatum* and *Oidiodendron kalrai* in mice. Mycopath. et Mycol. Appl. *37*(1):97-103.

Tewari, R. P. and C. R. Macpherson. 1968b. Pathogenicity and neurological effects of *Oidiodendron kalrai* for mice. J. Bact. *95*(3):1130-1139.

Tewari, R. P. and C. R. Macpherson. 1971. A new dimorphic fungus, *Oidiodendron kalrai*: morphological and biochemical characterisitics. Mycologia 63:602-611.

Tewari, R. P., C. R. Macpherson and T. K. Maitra. 1969. Serological and skin test cross-reactivity between *Histoplasma capsulatum* and *Oidiodendron kalrai*. Mycopath. et Mycol. Appl. 39(2):113-120.

Tokumasu, S. 1973. Notes on Japanese *Oidiodendron*. Trans. mycol. Soc. Japan 14:246-255.

Tubaki, K. 1960. Imperfect stage of *Onygena corvina* and its perithecial formation under culture. Bull. Nat. Sci. Mus. (Tokyo) 5(1):36-43.

Udagawa, S.-I. 1963. Notes on some Japanese Ascomycetes. I. Trans. mycol. Soc. Japan 4(4):94-100.

Udagawa, S.-I. 1966. Notes on some Japanese Ascomycetes. III. Trans. mycol. Soc. Japan 7(2-3):91-97.

Varsavsky, E. and L. Ajello. 1964. The perfect and imperfect forms of a new keratinophilic fungus *Arthroderma ciferrii* sp. nov.: *Trichophyton georgii* sp. nov. Revista di Patologia vegetale, Ser. 3, 4:351-363.

Varsavsky, E. and G. F. Orr. 1971. A new genus of the Gymnoascaceae. Mycopath. et Mycol. Appl. 43(2):229-234.

Visset, M.-F. 1974. Quelques Gymnoascaceae observees au microscope electronique a balayage. Mycopath. et Mycol. Appl. 54(3):377-383.

von Arx, J. A. 1970. The Genera of Fungi Sporulating in Pure Culture. Verlag-Cramer, Lehre.

von Arx, J. A. 1971. On *Arachniotus* and related genera of the Gymnoascaceae. Persoonia 6(3):371-380.

von Arx, J. A. 1972. On *Endomyces*, *Endomycopsis* and related yeast-like fungi. Ant. van Leeuw. 38(3):289-309.

von Arx, J. A. 1973. Further observations on *Sporotrichum* and some similar fungi. Persoonia 7(2):127-130.

Voordouw, G., G. M. Gaucher and R. S. Roche. 1974. Physiochemical properties of thermomycolase, the thermostable, extracellular serine protease of the fungus *Malbranchea pulchella*. Can. J. Chem. 52(11):981-990.

Vuillemin, P. 1911. Les aleuriospores. Bull. Soc. Sci. Nancey. III, *12*:151-175.

Wakefield, E. M. and G. R. Bisby. 1941. List of hyphomycetes recorded for Britain. Trans. Brit. mycol. Soc. *25*:49-126.

Wang, C. J. K. 1965. Fungi of Pulp and Paper in New York. State Univ. College of Forestry, New York.

Weitzman, I., I. Kozma and M. Silva-Hutner. 1969. Some observations on *Arthroderma uncinatum*. Sabouraudia *7*:216-218.

Weitzman, I. and M. Silva-Hutner. 1967. Non-keratinous agar media as substrates for the ascigerous state in certain members of the Gymnoascaceae pathogenic for man and animals. Sabouraudia *5*:335-340.

Weresub, L. K. 1973. *Oidium* (Fungi) nom. cons. prop. Taxon *22*:696-701.

Weresub, L. K., D. Malloch, and K. A. Pirozynski. 1974. Response to Hawksworth and Sutton's proposal for Art. 59. Taxon *23*(4):569-578.

Williams, J. I. and G. J. F. Pugh. 1974. Fungal biological flora: *Chrysosporium pannorum* (Link) Hughes 1958. International Biodeterioation Bulletin *10*(3):75-80.

Wilson, E. E. 1947. The branch wilt of Persian walnut trees and its cause. Hilgardia *17*(12):413-430.

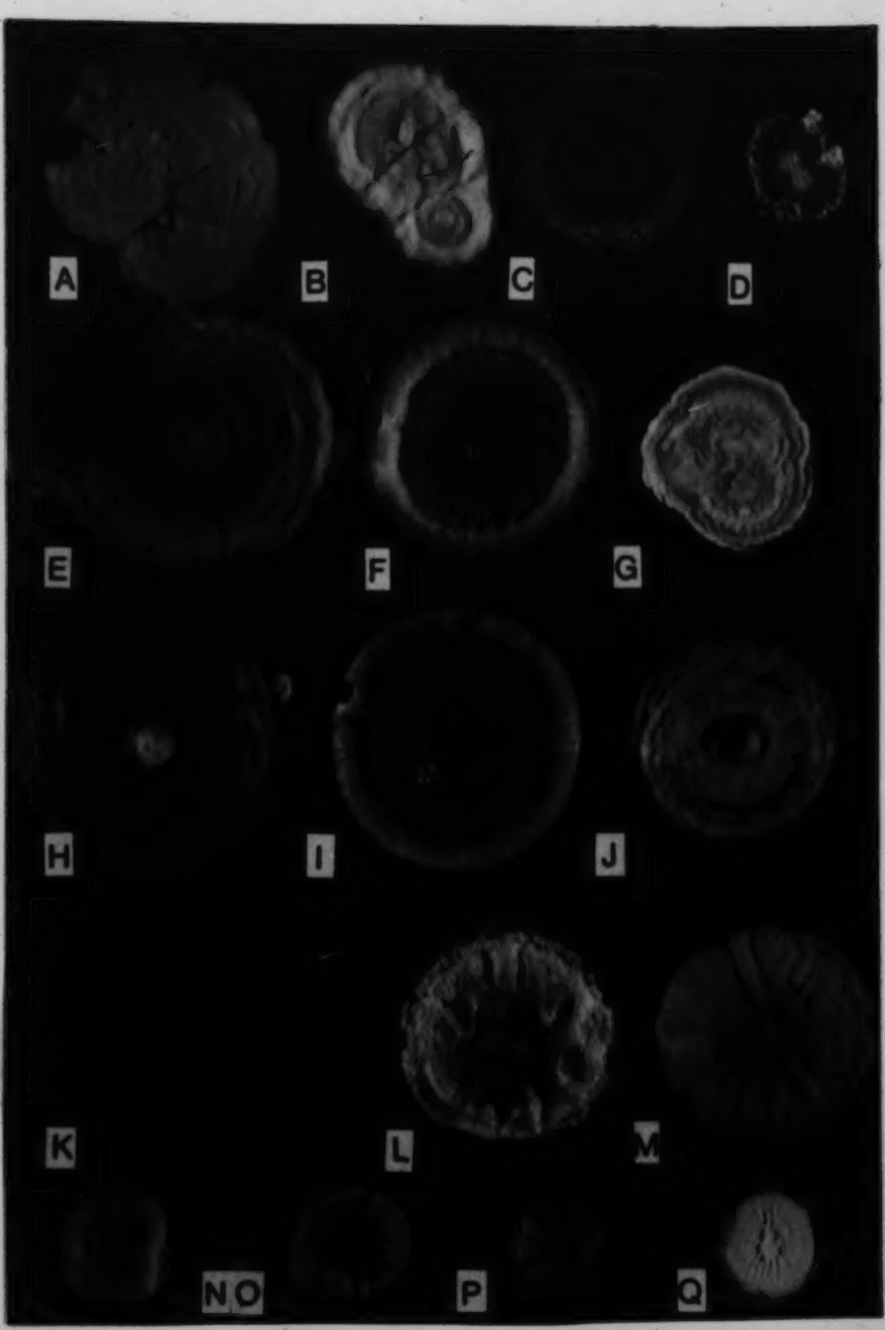
Wilson, E. E. 1949. The pycnidial state of the walnut branch wilt fungus, *Exosporina fawcetti*. Phytopathology *39*:340-346.

Windisch, S. 1951. Zur biologie und systematik des milchschimmels und einiger ahnlicher formen. I. Der milchscimmel (*Endomyces lactis*) und *Endomyces Magnusii*. Beitrage zur Biologie der Pflanzen *28*:69-130.

Wood, F. C. 1957. Diseases of cultivated mushrooms. Nature *179*:328.

APPENDIX

Figure 21. Colonies of *Malbanchea* species and *Auxarthron conjugatum* after 21 days at 25 C, except K at 37 C. Fig. 21A. *M. albolutea* (UAMH 1846 on PYE). Fig. 21B. *M. arcuata* (2983 on PYE). Fig. 21C. *M. arcuata* (3877 on cereal). Fig. 21D. *M. circinata* (3589 on cereal). Fig. 21E. *M. aurantiaca* (3705 on PYE). Fig. 21F. *M. aurantiaca* (3660 on cereal). Fig. 21G. *M. fulva* (2849 on PYE). Fig. 21H. *M. chrysosporoidea* (2288 on PYE). Fig. 21I. *M. chrysosporoidea* (2288 on cereal). Fig. 21J. *Auxarthron conjugatum* (3817 on PYE). Fig. 21K. *M. sulfurea* (3747 on PYE). Fig. 21L. *M. flava* (2865 on PYE). Fig. 21M. *M.* state of *Uncinocarpus reesii* (2847 on PYE). Fig. 21N. *M. flavoroseus* (1051 on cereal). Fig. 21O. *M. pulchella* (1560 on cereal). Fig. 21P. *M. flocciformis* (3273 on PYE). Fig. 21Q. *M. gypsea* (1841 on cereal). All x 0.60.


A
B
C
D
E
F
G
H
I
J
K
L
M
NO
P
Q

INDEX OF GENERA AND SPECIES

A page number followed by an asterisk (*) indicates an illustration.

Actinodendron verticillatum 193
Actinomyces bolognesii-chiurcoi 167
Aegerita crustacea 112
Allonema roseum 117
Arachniotus 65
   flavoluteus 64
   striatosporus 65
Arcuadendron 18-26,91
   ovatum 18, 21-25,24*
   triangularis 24*,25-26
Arthrographis 26-36
   langeroni 27-33,30*
   cuboidea 30*,33-36,40*,52,61,80
Aulographina pinorum 37
Auxarthron 125,131,136,175,227
   brunneum 137,218
   conjugatum 148,172*,175-178,180*
   thaxteri 137
   umbrinum 137,218
Bahusakala olivaceonigra 36-41,40*
Basidiomycotina 41-49,47*
Basipetospora rubra 50
Botryobasidium 78,169
Briosia 49-52
   ampelophaga 50-52
   azaleae 51
   cubispora 50
   cystopoides 52
   microspora 33
Byssoascus 63,65
   striatosporus 64,65
Ceriomyces albus 90
Chrysosporium 52-53,81,127,153,219,227
   corii 52
   merdarium 52
   pannorum 53,85
Cladosporium cubisporum 50,54
Coccidioides 53-54
   immitis 53,54,189,212*,214-216,217
Collybia 42
   conigena 45,47*
   velutipes 42,48
Cookeina sulcipes 77
Coprotrichum 117
   cinereum 117
   crustaceus 119
   lutescens 119
   purpurascens 117

- Coremiella 50,54-56,112,126
  - cubispora 50,52,54,68*
  - cuboidea 33,54
  - cystopoides 54
  - ulmariae 33,54
- Coremium luteolum 51
- Endoconidium luteolum 119
- Endomyces 57
  - geotrichum 57
  - magnusii 57
- Exosporina 106
  - fawcetti 106,107
  - laricis 106
- Fusidium 216
- Geomyces vinaceus 85
- Geotrichella 55
  - alternata 55
  - arctica 55
- Geotrichum 27,42,44,56-62,118,127
  - amycelicum 59
  - candidum 57
  - cinnamoneum 61
  - cuboideum 33,61
  - dulcitum 61
  - flavo-brunneum 61,101
  - fragrans 60
  - gracile 60
  - hirtum 60
  - klebahnii 60
  - microsporum 33,61
  - purpurascens 117
  - roseum 62,117
  - rotundatum 62
  - rugosum 62
  - state of Endomyces magnusii 60
  - suaveolens 62
  - vanriji 60
- Glycophila 122
- Gymnoascus 136,227
  - rhousiogongylinus 85
  - setosus 71
  - umbrinus 137
  - uncinatus 212
  - verticllatus 193
- Hendersonula toruloidea 106-109
- Malbranchea 18,52,54,62,79,81,112,122-131
  - albolutea 131-140,134*
  - arcuata 134*,140-142
  - aurantiaca 142-151,146*,176
  - bolognesii-chiurcoi 167
  - chrysosporoidea 151-157,155*
  - circinata 155*,157-163,161*
  - dendritica 180*,189-193,201*,215
  - flava 193-202,201*

  - flavoroseus 161*,163-167,171*
  - flocciformis 203-207,206*
  - fulva 206*,207-209
  - gypsea 190,209-213,212*,215
  - kambayashii 167
  - pulchella 122,123,167-175,172*,181,204
  - pulchella var sulfurea 169,181,182
  - pulveracea 168
  - state of Auxarthron conjugatum 172*,175-178,180*
  - state of Coccidioides immitis 54,189,212*,214-216
  - state of Uncinocarpus reesii 216-236,222*,225*
  - sulfurea 123,178-189,180*
- Monilia miniata 118
- Moniliella suaveolens 62
- Mucor crustaceus 112
- Myxotrichum 63,65,128,158,163,217
  - aeruginosum 166
  - brunneum 137
  - cancellatum 64
  - carminoparum 162
  - chartarum 163
  - conjugatum 175
  - deflexum 166
  - emmonsii 218
  - herbariense 136
  - setosum 68*,70,76*,79,80
  - stipitatum 162,166
  - striatosporus 65,68*
  - thaxteri 137
- Neurospora crassa 41
- Oidiodendron 27,45,48,62-77,127
  - fuscum 63
  - kalrai 27
  - state of Myxotrichum setosum 68*,70,76*,79,80
  - state of Myxotrichum striatosporus 65,68*
  - tenuissimum 63
  - truncatum 63
- Oidium 78-79
  - aurantiacum 119
  - aureum 78
  - microspermum 70,79
  - pulveraceum 168
  - rubens 112
  - rubrum 119
- Ojibwaya 51,107
- Oligoporus 91
  - farinosus 91
  - ustilaginoides 91
- Oncocladium flavum 193,201*
- Onygena 86
  - corvina 86,126
  - piligena 86
- Oospora 79-80,122
  - crustacea 80,110,112,118

  - cuboidea 33,80
  - fragrans 60
  - klebahnii 60
  - microsperma 70
  - sulphurea-ochracea 84
- Ovadendron 80-90
  - asperulatum 76*,81-83
  - pannorum 53,84-90,88*
  - sulphurea-ochracea 83,88*
- Periconia 51,63
  - azaleae 51
  - tenuissima 63
- Petalosporus 228
- Phlebia radiata 45
- Polyporus ptychogaster 90
- Protendomycopsis 61
  - domschii 61
  - dulcita 61
- Pseudogymnoascus 85,136
  - roseus 85
- Ptychogaster 90
  - albus 88*,90
  - fuliginoides 90
  - rubescens 91
- Rhinotrichum pulveraceum 168
- Scopulariopsis casei 119
- Scytalidium 92-109
  - acidophilum 100-101,104*
  - album 88*,96-98
  - aurantiacum 99-100
  - fawcetti 107
  - flavobrunneum 61,101-106,104*
  - lignicola 88*,93-96
  - state of Hendersonula toruloidea 104*,106-109
- Septonema olivaceo-nigra 37
- Shanorella 228
- Sporendonema 48,109-121,126
  - artemisiae 120
  - casei 80,112-114,116*
  - epizoum 118,121
  - purpurascens 62,116*,117-120
  - roseum 117
  - roseum var album 121
  - salicis 120
  - sebi 121
  - terrestre 111,121
- Sporocybe azaleae 51
- Sporotrichum 78
  - aureum
  - merdarium 52
  - pannorum 84
- Stysanus ulmariae 33,54
- Thermoideum sulfureum 122,167,181
- Torula 110,112

   casei 110,112
   sporendonema 110,112
Toxotrichum cancellatum 64
Trichoderma 78
   aureum 78
   dubium 78
Trichosporon 34,60
   cutaneum 61,62
Tyromyces ptychogaster 90
Uncinocarpus reesii 216-236,222*,225*
Wallemia sebi 61,118,121